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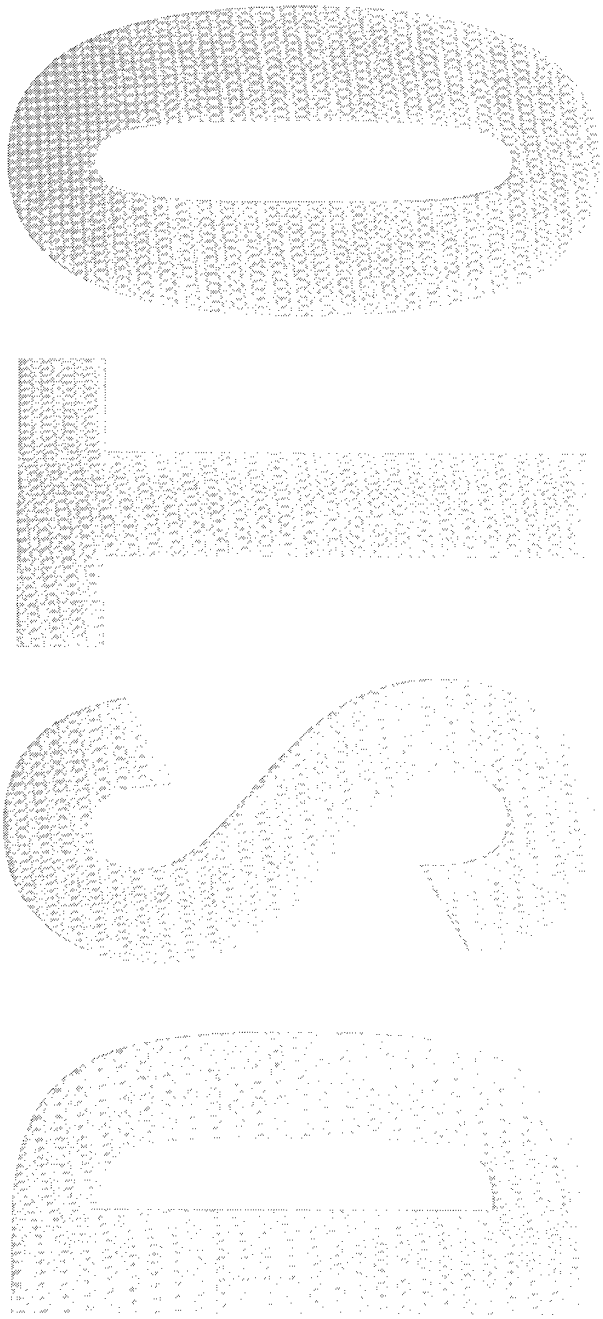

A Framework Study for Australian Defence Organisation (ADO) Architecture Practice

Phase 1 - Client Report (Part 2) Architecture Practice Study

P. Chen and G. Bulluss

DSTO-CR-0152

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ABSTRACT

Successful development and evolution of the Defence Information Environment requires the organisation to develop an architectural culture in its Information Technology (IT) practice and future organisation development. In such a culture, the organisation must achieve an integrated architecture capability for high-level knowledge creation, management and reuse within its improved IT development capability. This report discusses the main issues facing the organisation in developing such an integrated architecture capability, and proposes employing architecture practice concepts at the level above individual architecture development. High-level management and integration solutions associated with architecture practice, and responsibilities of relevant parties are also discussed in the report to help reach a shared understanding of the practice required by the ADO. The report aims to provide a basis or context for the Architecture Review Board to plan and organise the architecture practice and to produce more detailed guidelines.

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Executive Summary

According to the Defence Information Environment (DIE) Strategic Plan, development of architecture practice for the Australian Defence Organisation (ADO) is one of the three main activities associated with developing ***an architectural approach*** for successful development of the Defence Information Environment. Such an architecture practice is an agreed method to guide, plan, formulate, review, manage, coordinate, maintain, publish and use architectures throughout the defence community. Investigating rational and practical solutions for successfully developing ADO architecture practice has been the main focus of the Architecture Practice Study task DSTO (JNT99/017). This report is Part 2 of the Phase 1 Client Report of the task.

This study discusses architecture issues in the context of the whole ADO, and in particular issues relating to C4ISR systems. Architecture is considered in a broad context as knowledge about a system, with this knowledge being described and represented by a set of views that together reflect the concerns and requirements of the stakeholders of the system. In discussing these issues the three critical roles of architecture are illustrated, with these being: a picture of the current state; a blueprint or vision for the future; and a roadmap as guidance on how to get there.

Based on the context analysis and principles study of architecture practice presented in Part 1 of the Phase 1 Client Report, this report presents a framework study for ADO architecture practice. Through briefly reviewing the history of ADO architecture practice, and the experience and achievements of the US DoD in architecture practice, the report initially presents a background study. The investigation into the requirements of architecture practice for the ADO reveals that the ADO architecture practice should target the improvement of ADO's Information Technology (IT) development capability or future organisation development capability as the main objective, since any use of architecture is part of implementing this capability.

The use of architecture is not limited to system design and development. It can also be used as a way to bring together the various stages of capability development and support. A working paradigm is presented that shows the relationship between architecture knowledge and the four aspects in the cycle of capability development and support. These four aspects are: research and development for future capability; enterprise planning and business description; system development and general IT guidance; and system management and maintenance.

In fulfilling its roles across the various aspects of capability development and support, architecture can be seen as having six main attributes determining its context in multiple dimensions. These attributes are: object/system associated; role (of the architecture); view type; time ("as-is" or "to-be"); methodology used; and tool used. Without clear specifications on these attributes, the value of a specific architecture can not be clearly presented. It is these inherent attributes that create complicated relationships amongst various architecture views or products.

In order to successfully support the Defence Information Environment, the ADO requires an **integrated architecture capability** that can successfully evolve over time and become part of the organisational culture. While developing individual architecture products does provide a limited capability, the integrated development of architecture is required to satisfy the broad needs of the ADO. The aim should be to develop a mature architecture culture in which any architecture is developed in a well-defined context, at the right time, using an appropriate methodology, and is one that can be integrated with others and used widely and effectively.

Using a high-level conceptual model of the IT development capability required by the ADO, the study identifies the main architecture-based capabilities that can support different aspects of the IT development capability. These include various descriptive and supporting architecture products, architecture repositories, advanced architecture-based systems planning, modelling, simulation and measurement of performance. *An **integrated architecture capability*** is believed necessary and important for improvement of future organisation development capability.

Through applying the principles that *a **disciplined architecture practice*** should use as proposed in Part 1 of the Client Report, the report discusses the main interests and responsibilities of the Chief Information Architect and the DIE Architecture Office (DIEAO). Also discussed is the proposal that architecture practice concepts at the level above individual architecture development should be adopted. Based on such thinking, three main views of managing architecture practice—architecture product view, process/methodology view and tool/environment view—are discussed with certain methods and solutions. The main challenges in ADO architecture practice are how to clarify the value of each architecture and fully realise it in practice.

Success in architecture for the ADO will rely on the well-organised community practice in which the core business is not only production, but also more importantly sharing, management, evolution and reuse of organisation business knowledge and systems and IT knowledge through using the concept of architecture.

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Abbreviations

ABC	Architecture Business Cycle
ACC	Architecture Coordination Council (US DoD)
ACG	Architecture Coordination Group (US DoD)
ADF	Australian Defence Force (ADO)
ADO	Australian Defence Organisation
AF	Architecture Framework
APSE	Architecture Practice Supporting Environment
ARB	Architecture Review Board (ADO)
AST	Australian Theatre (ADO)
AWG	Architecture Working Group (US DoD)
BCSS	Battlefield Command Support System (ADO)
C2	Command and Control
C3	Command, Control and Communications
C3I	Command, Control, Communications and Intelligence
C3I/IO	Command, Control, Communications and Intelligence/Information Operations
C4	Command, Control, Communications and Computers
C4I	Command, Control, Communications, Computers and Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
C4ISR AF	C4ISR Architecture Framework (US DoD)
CADM	Common Architecture Data Model (US DoD)
CASE	Computer Aided Software Engineering
CAW	C4ISR Architectures for the Warfighter (US DoD)
CCA	Command C4ISR Architecture (US DoD)
CIA	Chief Information Architect (ADO)
CIAP	Command Intelligence Architecture Program (US DoD)
CINC	Commander-In-Chief (US DoD)
COE	Common Operating Environment
CORBA	Common Object Request Broker Architecture
CRC	Co-operative Research Centre (Australia)
CRISP	Canberra Regional Information Systems Project (ADO)
CTD	Concept Technology Demonstrator
DAO	Defence Acquisition Organisation (ADO)
DARPA	Defense Advanced Research Projects Agency (US DoD)
DBMS	Database Management System

Abbreviations (Cont)

DCE	Distributed Computing Environment
DDDS	Defense Data Dictionary System (US DoD)
DE	Domain Engineering
DIE	Defence Information Environment
DIEB	Defence Information Environment Board (ADO)
DII	Defense Information Infrastructure (US DoD)
DISA	Defense Information Systems Agency (US DoD)
DISG	Defence Information Systems Group (ADO)
DJFHQ	Deployable Joint Force Headquarters (ADO)
DMSO	Defense Modelling and Simulation Office (US DoD)
DSTC	Distributed Systems Technology Centre (Australia)
DSTO	Defence Science and Technology Organisation (ADO)
EAS	Enterprise Architecture Strategies (Meta group)
EDCS	Evolutionary Design of Complex Software (US DoD)
EW	Electronic Warfare
EWTA	Enterprise Wide Technical Architecture (Meta group)
EXC3ITE	Experimental C3I Technology Environment (ADO)
HLA	High Level Architecture
HQAST	Headquarters Australian Theatre (ADO)
IO	Information Operations
ISR	Intelligence, Surveillance and Reconnaissance
IT	Information Technology
ITDC	IT Development Capability
ITF	Integrated Task Force (US DoD)
JCAPS	Joint C4ISR Architecture Planning/Analysis System (US DoD)
JCSS	Joint Command Support System (ADO)
JFC	Joint Force Commander (US DoD)
JISS	Joint Intelligence Support System (ADO)
JOA	Joint Operational Architecture (US DoD)
JSA	Joint Systems Architecture (US DoD)
JTA	Joint Technical Architecture (US DoD)
JTF	Joint Task Force (US DoD)
KRAF	Knowledge Repository Architecture Framework
LISI	Levels of Information Systems Interoperability (US DoD)
OA	Operational Architecture

Abbreviations (Cont)

OASD (C3I)	Office of the Assistant Secretary of Defense for Command, Control, Communications and Intelligence (US DoD)
ODM	Organisation Domain Modelling (US DoD)
OS	Operating System
R&D	Research and Development
RM-ODP	Reference Model - Open Distributed Processing (OSF)
RTI	Runtime Infrastructure (US DoD)
SA	System Architecture
SE	Software Engineering
SHADE	Shared Data Environment
SOS	System of Systems
STARS	Software Technology for Adaptable, Reliable Systems (US DoD)
TA	Technical Architecture
TAFIM	Technical Architecture Framework Information Management (US DoD)
TOGAF	The Open Group Architecture Framework
TRM	Technical Reference Model (US DoD)
TTP	Tactics, Training and Procedures (US DoD)
UJTL	Universal Joint Task List (US DoD)
UK MOD	United Kingdom Ministry of Defence
US DoD	United States Department of Defense

1. Introduction

The importance of and reliance on information systems architectures has grown steadily over the last decade as computer-based systems throughout the Australian Defence Organisation (ADO) have become larger, more complex and more interconnected. Apart from coping with the common set of symptoms in IT practice mentioned in Section 1 of Part 1, the ADO is now facing greater challenges in seeking solutions for implementing new technologies in response to the changing needs of the business. Acquisition of systems of systems will further increase the magnitude of complexity that will have to be managed if the systems of systems concept is to become a reality.

Australia's Strategic Policy, 1997 assigns the highest capability development priority to achieving the *Knowledge Edge*. Developing the Defence Information Environment (DIE) is seen as one of the key tasks required to realise the knowledge edge. In order to be able to successfully carry out such a task, the ADO needs to first examine what kind of development capability is required, and whether the existing capability is ready to deliver what is expected for the DIE. The quality level and success of the DIE is largely determined by the level of this development capability, which should be much more comprehensive than that used for a single project or individual system development.

The historical experience and current situation of IT practice in the Department shows that improvement of IT practice or IT Development Capability (ITDC) is a challenging issue that is waiting for better solutions. Without significant improvement of the ADO's IT development capability, the DIE development will face significant uncertainty.

Architecture Practice is an emerging discipline that is aimed at systematically addressing principles of generation, management, evolution, use and reuse of architecture in the context of evolutionary development of systems of systems within a large organisation. Introducing such a discipline within an organisation is seen as a culture change or culture development that can gradually facilitate architecture capability developing and becoming an effective organisational capability.

Part 1 of this report addresses the main issues of architecture practice in general for large organisations, including definitions of architecture, confusion and complexity in architecture, comparison of architecture frameworks or approaches, and maturity level of architecture practice. An Architecture Knowledge Value Chain based Architecture Practice Conceptual Model for large organisations is discussed in Part 1. This model can be used as a basis to either examine coverage of existing architecture frameworks, or to plan and manage at a high level architecture practice for a large organisation.

This part of the report will study specifically the context of the ADO's architecture practice, including history, achievements, current situation and comparison with architecture practice of US DoD. The main objectives of the study are to assist the Defence Information Environment Board (DIEB) and the Architecture Review Board (ARB) in:

- Developing architecture as a specific capability of the organisation in its future development;

- Developing an integrated architecture capability through which the ADO can understand, develop and manage the Defence Information Environment (DIE) in an efficient and cost effective manner; and
- Maturing the ADO's capability in C4ISR systems development (including planning, designing, simulating/modelling and evaluating) through using architecture practice.

The study mainly focuses on:

- a common understanding that can be shared by all relevant parties;
- the philosophy of achieving a mature enterprise-wide architecture practice;
- the context and management study of ADO's architecture practice;
- architecture practice planning and decision making; and
- investigation into architecture practice as a fundamental discipline for overall IT practice improvement.

The output of the framework study of architecture practice will be a management framework for the ADO to improve its IT Development Capability (ITDC) through using architecture. In Phase 1 of the research task, the study initially provides academic and technical analysis of R&D in architecture and proposes a rudimentary version of such a framework. This framework is oriented towards achieving effective generation, management and re-use of knowledge or architecture in IT practice.

The study shows that developing a disciplined architecture practice, which includes architecture products, architectural methodologies and supporting environments, enhances the IT development capability. A better understanding of IT development capability helps us in planning architecture practice, and developing overall control mechanisms for architectural methodology coordination and architecture product management.

Specifically, the framework study on architecture practice for the ADO aims to:

- Investigate the R&D context where various architectural issues arise (discussed in Part 1);
- Discuss concepts and principles of architecture and architecture frameworks (discussed in Part 1);
- Evaluate and compare architecture-based methodologies (discussed in Part 1);
- Examine current architecture practice in both US DoD and the ADO;
- Identify both opportunities and difficulties in architecture related practice;
- Provide a management framework of architecture practice;
- Propose strategic directions for the ADO to improve IT development capability through use of rationalised architecture practice;
- Develop a framework for the ADO to plan and develop an Integrated Architecture Capability for its future development, including C4ISR domains;

- Assist the ADO in the planning and initialisation of architecture related R&D in order to avoid various problems caused by ill-planned practice; and
- Make recommendations on process innovation and initiatives in architecture practice.

The study does not, however:

- Produce any design of architectures for particular systems;
- Study any technology-dependent integration solution;
- Provide specific suggestions, at this stage, on which architecture methodologies should be adopted by the ADO;
- Attempt to make any architecture decision on ADO's behalf; or
- Intend to educate developers in detail about how to employ particular methodologies.

An important feature of this study is its comprehensiveness in addressing broad architecture issues and their relationship to the improvement of the organisation's IT development capability.

It is suggested that in order to better understand issues discussed in this report, that readers first peruse the Part 1 of the Phase 1 Report, or use it as a reference.

2. Architecture Practice and C4ISR Capability Development

The US DoD C4ISR Architecture Framework (C4ISR Architecture Working Group, 1997) begins with the following quote:

"The Defence Science Board and other major studies have concluded that one of the key means for ensuring interoperable and cost effective military systems is to establish comprehensive architectural guidance for all of US DoD."

This statement demonstrates the US DoD belief that architecture practice is required to ensure that C4ISR capabilities meet the requirements of warfighters.

The main reasons for the ADO to consider an overall architectural guidance are:

- In order to successfully deliver improved IT capability for core business areas, the ADO needs adequate capability to effectively generate, manage and reuse knowledge in IT practice as a first step towards an improved overall development approach.
- Wide use of the concept of architecture by the defence community requires better methods of architecture production and management that maximise the value of architecture and architecture practice.
- On many occasions both defence and industry representatives have expressed the belief that the chaotic situation of IT practice in the organisation will not end unless significant cultural change and process innovations are introduced.

C4ISR systems development requires the organisation to pay more attention to architecture practice rather than just individual architecture products. Without a sophisticated understanding and effective management of architecture practice, it is difficult for the organisation to achieve a high level of IT development capability that could meet the needs of knowledge-based warfare.

2.1 Use of Architecture for C4ISR

The task of C4ISR systems development is carried out in an evolutionary development process if the ADO is considered as a whole. It involves such activities as planning, research, system development, acquisition and support and management of individual systems, as well as the overall system of systems. The context for this task has gradually formed and relied on a body of knowledge, which covers the following areas:

- Individual system/capability development (the systems are largely developed by industry but managed by the Department);
- Capability study and system synthesis, including:

  C2 capability study;
  Military Information Operation capability study;
  Joint Vision;
  Individual concepts/systems and joint systems or systems of systems (SOS);
  System or SOS simulation/modelling.

- IT environment study and development, including:

  COE/Technical Architecture Framework /Reference Architecture;
  Interoperability;
  Standards/policy.

- Methodologies, such as:

  Architecture frameworks;
  Software Engineering (SE);
  Domain Engineering (DE).

Because of the complexity of the ADO's IT practice, there has been a variety of demands in using concepts of architecture and architectural methodologies. It should be appreciated that many individual architecture products or *ad hoc* architectural approaches can be developed and used to address certain aspects of architecture practice. On the other hand, however, questions and confusion generated from the practice are various, with these falling mainly in two sectors:

- In traditional IT practice, such as:

  How can architecture products be developed effectively and coherently?

  How can different architectural methodologies be well coordinated in the practice?

  Is there a unified architectural methodology that meets various needs?

  How can architecture be used to improve the acquisition process of IT capability?

- In C4ISR capability development, such as:

  How can C4ISR and warfighting capability development be supported by architecture?

  How can an architectural methodology, such as the C4ISR Architecture Framework, and its products, be successfully integrated with other IT-related R&D activities and the culture of the ADO, so that architecture practice can be supported as broadly as possible?

  How can the C4ISR Architecture Framework be used by the ADO and in what manner?

2.2 Roles of Architecture

Traditional disciplines of computing and information systems do not systematically address how the complicated task of developing and managing C4ISR systems could be carried out coherently and in an integrated manner. One of the biggest challenges is the formulation of an overall development approach that can meet the specific requirements of IT development capability for the ADO, while ensuring that individual activities can be conducted coherently within a given context. This approach needs to:

- Enable outcomes of these activities to be successfully integrated and maximally used in practice;
- Ensure better generation, management and reuse of architecture knowledge so that this body of knowledge can be treated as an asset of the organisation; and

- Lead to maturation of the organisation's IT development capability.

Architecture can contribute measurably to integration, interoperability, insertion of technology, cost reduction and organisation knowledge management. As pointed out in Part 1 of this report, the roles of architecture are presented in the three distinct areas in which architecture is used:

- A picture of the current state;
- A blueprint or vision for the future; or
- A roadmap as guidance on how to get there.

For any specific architecture its role is always limited to one of these and varies depending on a number of factors, such as scope and comprehensiveness. In order to get the full benefits of architecture from all its three main roles, an integrated architecture capability is required by the ADO. The requirements for this future development capability are discussed in Section 5.

The development of an integrated architecture capability is critical to the defence organisation, but is also a challenging task. Currently, some disparate architecture capabilities have been developed independently. Individual architecture capabilities and roles need to be combined to jointly provide support for the improvement of the IT development capability, through the integrated architecture capability generated from well-planned and well-developed architecture practice.

3. Experience and achievements of the US DoD

In order to improve its IT development capability, in particular for successful and evolutionary acquisition of C4ISR capabilities, the US DoD has started to develop its practices in various areas of architecture. It was necessary for the US DoD itself to do this since industry practices in architecture cannot meet its specific needs, and most of them independently address certain issues of architecture practice required for the acquisition process.

3.1 Management of US DoD Architecture Practice

Issues occurring in architecture practice management have attracted attention from various levels of the US DoD. Two main groups were set up to assist the Office of the Assistant Secretary of Defense for C3I, USA, in developing and managing the overall architecture practice of the US defence organisation.

C4ISR Architecture Working Group (AWG) was set up in 1996 with representatives from various parts of the Department and has two main objectives:

- implementation of the recommendations made by the Architecture Panel of the C4ISR Integrated Task Force (ITF); and
- identification and resolution of other appropriate C4ISR Architecture issues.

Six panels were formed within the AWG to concentrate on six different areas:

- Architecture Framework;
- C4ISR Interoperability;
- Coalition Issues;
- Architecture Data Models and Tools;
- US DoD Architecture Roles and Responsibilities;
- Integration of the five areas above.

The main achievements and outcomes are briefly discussed in the following section.

Architecture Coordination Council (ACC) was set up in 1997 and has an action arm called the Architecture Coordination Group (ACG) that is responsible for continuous guidance, review, integration and coordination among all relevant agencies. Indeed, it was required that the ACG serve as the executive secretariat of the ACC, and ensure that all work of the ACC and its supporting groups is completed, integrated and brought to the ACC for appropriate review, revision and approval.

In 1998, the AWG recommended the establishment of a multi-domain architecture working group with appropriate US DoD community-wide representation whose charter would be to support the US DoD CIO in developing a US DoD Information Technology Architecture.

3.2 Achievements

The US DoD has led architecture practice in the area of C4ISR during the last two decades. The main achievements are in four sectors:

- Supporting Architecture Products;
- Architecture Methodologies;
- Architecture Descriptions and Repositories;
- Supporting Tools/Environments.

Each of the sectors is discussed further below.

3.2.1 *Supporting Architecture Products*

A set of corporate-based supporting architecture products, also called *universal reference resources,* has been developed in the US DoD's architecture practice, including:

- **TAFIM** and **TRM**
  The Technical Architecture Framework Information Management (TAFIM) (version 3.0) (DISA, 1996[b]) is a set of eight volumes consisting of very specific guidance on building and maintaining US DoD systems architectures. It provides guidance for the evolution of the US DoD technical infrastructure. The TAFIM does not provide a specific system architecture. The TAFIM US DoD Technical Reference Model (US DoD TRM) defines the target technical environment for the acquisition, development, and support of US DoD information technology through proving a common conceptual framework and a common vocabulary.

- **CADM**
  The Core Architecture Data Model (CADM) (CAWG, 1997[b]) is intended to provide a common meta-model, or (logical) schema, for repositories of architecture information. It enables storage of architecture products from multiple framework-based architecture projects in a common way such that products from different projects can be jointly analysed and compared.

- **LISI**
  The Levels of Information Systems Interoperability (LISI) is a product that supports users at all levels and defines a maturity model, capabilities and implementation options, and an interactive process for improving systems.

- **DII COE**
  The DII Common Operating Environment (DII COE) (DISA, 1996[a]) defines software portability and application-to-operating environment interactions.

- **SHADE**
  The Shared Data Environment (SHADE) is a set of common data models.

- **JOA/JSA/JTA**
  The Joint Operational Architecture (JOA), Joint Systems Architecture (JSA) and Joint Technical Architecture (JTA) are three main views that jointly with other common building blocks support the C4ISR architecture development through

using the C4ISR Architecture Framework described later in this section. JTA establishes the minimum set of rules governing information technology within US DoD systems, including standards for information processing, information transfer, the structure of information and data, human-computer interface standards for information entry and display, and information security standards. JTA is based on previous works of TAFIM, TRM and DI COE.

JSA and JOA are yet to be developed.

- **JTF Reference Architecture**
  The Joint Task Force (JTF) Reference Architecture is a specification of the US DoD force structure and operational guidance.

- **C4ISR Architectures for the Warfighter (CAW)**
  The C4ISR Architectures for the Warfighter (CAW) Program develops critical C4ISR baseline (Contingency Planning) and objective architectures (investment decisions) and companion TTPs at the Unified Commands. This program begins with the original CIAP organisational focus—the CINC/JFC level with contributions from National Agencies, the Services, and the Supporting Commands —and extends this focus from the JFC down through the Joint Force functional and service components. In other words, it begins with an overarching Command C4ISR Architecture (CCA) which spans all UJTL functional areas and bounds the C4ISR scope. The analysis is then further focused through the development of three core architectures: a Command and Control (C2) architecture; an Intelligence Surveillance and Reconnaissance (ISR) architecture; and a Communications and Computers Infrastructure architecture. The C2 and the ISR architectures directly map to a primary "C4ISR" UJTL task, while the Computers and Communications Infrastructure architecture transcends and underpins all UJTL tasks. All CAW architectures are developed using a common structured approach, the C4ISR Architecture Framework 2.0 discussed in the next subsection.

Although these supporting products have been or will be developed by different teams for various reasons, a common purpose shared by them is to eventually and globally support better architecture practice as a whole rather than only for use of the C4ISR Architecture Framework. Considering these products as a set and applying the context analysis in Part 1, it is noted that an architecture practice supporting environment (APSE) for the US DoD is being gradually formed. One of the main challenges in architecture for the US DoD is whether these products can be successfully used in a combined manner and maintained or evolve consistently and coherently in practice.

3.2.2 *Architecture methodologies*

- **C4ISR Architecture Framework**
  This has been developed as a methodology for guiding development of architecture descriptions for warfighting domains and is also suggested for use more broadly within US DoD. The framework intends to provide general guidance for coherent use of a variety of IT achievements of US DoD mentioned above for C4ISR systems development.

The C4ISR Architecture Framework suggests that all development projects should adopt a unified architecture framework for integration of operations and systems. This means that in the course of building a given architecture description, a set of

architecture products of those graphical, textual and tabular items will be developed. Some products in this set are essential and some are supporting products. Using this framework, the US DoD is aiming to consistently define all C4ISR relevant system architectures using three main views, that is, Operational Architecture, System Architecture and Technical Architecture. However, these efforts will be carried out separately on a project basis. It is stated that all existing systems are to be re-described at some stage in this unified representation.

The C4ISR AF is a specific architecture development methodology for the C4ISR domain.

- **C4ISR Models**

In late 1996, the C4I Modelling, Simulation, and Assessment Directorate (D8) of DISA took an innovative approach and began developing the DISA C4ISR Model. The purpose of the model was to enhance the understanding of how information affects decision making. The DISA C4ISR Model is a High Level Architecture (HLA) compliant federation using a modified Runtime Infrastructure (RTI) based upon the HLA RTI version 0.33 developed by the Defense Modeling and Simulation Office (DMSO). Migration to the new HLA RTI version 1.3 is forecast to be completed in FY99.

- **Organisation Domain Modelling (ODM)**

Organisation Domain Modelling (Simos, 1996) is a domain engineering method developed in 1996 under the Software Technology for Adaptable, Reliable Systems (STARS) program and sponsored by the U.S. Defense Advanced Research Project Agency (DARPA). ODM builds on concepts that have emerged from the work of many researchers and practitioners in the field of systematic software reuse. The systematic reuse community has evolved the discipline known as domain engineering in an attempt to formalise software engineering processes and make the design of reusable software more repeatable, verifiable and methodical. The ODM method consists of three main phases, referred to as *domain planning, domain modelling,* and *asset base engineering*. Although this approach was originally introduced for improvement of software reusability, it has also suggested systematic improvement in handling domain models or architectures as organisational assets.

3.2.3 *Architecture descriptions and repositories*

There are a great number of descriptive products associated with existing systems in a diversity of representation forms from past development in various domains within the US DoD.

There has been no reporting of any efforts that aim to achieve an overall and integrated architecture description for all existing systems of the US DoD. However, it was mentioned that the C4ISR Architecture Framework would also be used for re-describing existing systems. It is not clear at this stage how the redescription of all existing systems is related to the development of the Joint Systems Architecture (JSA).

A **US DoD Architecture Information Repository** (CAWG, 1998 [b]) will be developed to provide for recording, and making available for review and reuse, instances of architectures and their architecture descriptions. Starting points for the repository

would be the Integrated Data Dictionaries for the Joint Technical Architecture and the Joint Operational Architecture.

3.2.4 *Supporting tools/environments*

- Joint C4ISR Architecture Planning/Analysis System (JCAPS)

  JCAPS is a supporting tool designed to facilitate use of the C4ISR Architecture Framework through access to supporting elements or universal references. It aims to provide its users with flexibility by allowing them to query the database in previously unthought of ways, discovering new relationships and more meaningful ways to show why and how those C4ISR capabilities are to be integrated. JCAPS prototypes produced during the first of two phases of a 4-phase development have been completed. Integrating JCAPS with other supporting elements (such as LISI and CADM) will generate more functions for various architecture purposes in broader areas.

3.2.5 *Other initiatives*

- **US DoD Architecture Framework** is referred to in the Final Report of the C4ISR Architecture Working Group but there is no detailed discussion.
- **US DoD Architecture Information Repository** is also referred to in the Final Report of the C4ISR Architecture Working Group but again there is no detailed discussion.
- **Evolutionary Design of Complex Software** (EDCS)
  EDCS is a program sponsored by DARPA which summarises technologies into five technology "clusters": 1) Rationale Capture and Software Understanding; 2) Architecture and Generation; 3) High Assurance and Real-time; 4) Design Management, and 5) Dynamic Languages.

3.3 Discussion

US DoD initiatives in architecture are both numerous and diverse. The achievements mentioned above are those within the authors' knowledge that they regard as relevant.

Since the C4ISR architecture framework is a mandated methodology for all US DoD projects, all new systems for warfighting should be developed using it and with a whole set of architecture products. The framework specifies which architecture products are required but does not elaborate on how the architecture products should be developed in detail, such as through which processes and using which tools and techniques.

The evolution process of the C4ISR Architecture Framework illustrated in Figure 3-1 shows the planned development (CAWG, 1998 [b]) to cover broader areas of the US DoD's IT development capability.

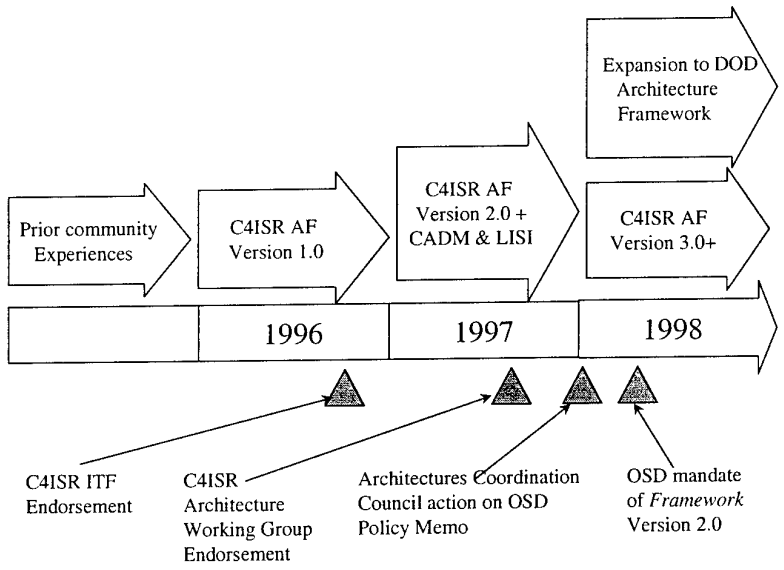

Figure 3-1. Evolution process of the C4ISR Architecture Framework

The trend is towards **a unified C4ISR development process** suggested by the AWG. This process will use a unified architecture practice supporting environment including a set of universal reference resources (or corporate supporting elements). However, relationships are yet to be clearly defined between or amongst the following elements (CAWG, 1998[b]):

- C4ISR Architecture Framework plus universal reference resources (common building blocks);
- US DoD's Architecture Framework (to be developed);
- US DoD's Information Technology Architecture (to be developed); and
- US DoD's Architecture Information Repository (to be developed).

Unfortunately, the progress in these areas has not been further reported.

The investigation into the current architecture practice of the US DoD shows that:

- An organisational commitment to architecture has been made;
- The architecture practice as a whole needs to be further defined when the strategic and global thinking relating to architecture practice becomes significantly clearer to all relevant areas;
- Management and coordination concerns need to be addressed to facilitate its successful evolution;
- The core and worthwhile part of the practice will become evident as more activities are carried out using the various architecture products and approaches; and
- The IT development capability of the organisation will be improved significantly if tools or environments, such as JCAPS, can be properly developed to integrate

architecture products and support use of architectural approaches (or architecture frameworks).

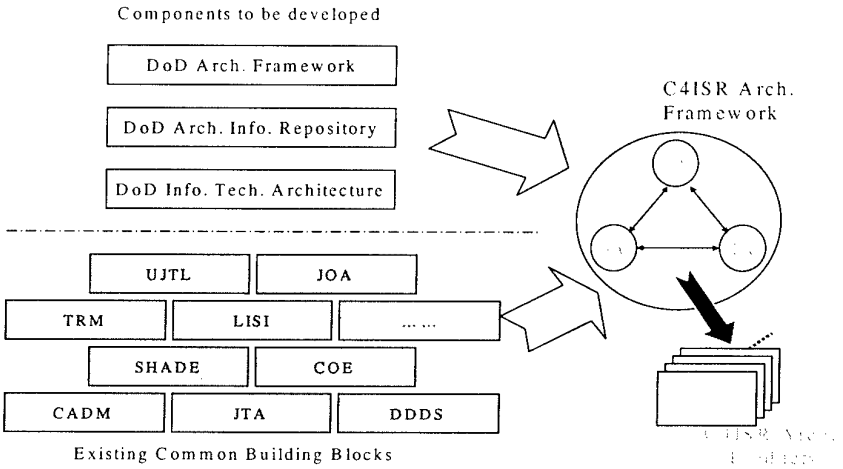

Figure 3-2. An architectural approach of the US DoD for developing C4ISR systems.

The unified C4ISR development process proposed by the US DoD C4ISR AWG shows that in the process there are other important aspects that are not covered by the Architecture Framework. It is very important to understand that any architecture or framework does not address the full range of problems and issues that are likely to be experienced in SOS development. Ideally, this unified process would work as follows (CAWG, 1998[b]):

- Distributed development of C4ISR operational, systems and technical architecture views would continue;
- Architectures would be easily compared and interrelated across organisational boundaries due to common look, touch, and feel;
- The US DoD components would leverage the integrable architecture(s) to:
  - Discuss and reconcile differences regarding common joint interactions
  - Examine applications of current and emerging technology
  - Look for leveraging opportunities
  - Identify and prioritise key systems interoperability problems and objectives
- Less obvious concepts would be tested for validity and cost-effectiveness prior to committing to a potentially costly acquisition or full-scale integration activity;
- Notions, ideas, concepts, limited demonstrations, and fielded capabilities could be traced back through the architecture audit trail to assess the impact on operational mission effectiveness.

Therefore, the AWG is aiming to enable the framework to evolve and to be integrated with a broader practice environment of IT business.

Based on the architecture practice context analysis in Part 1, we can map the current US DoD architecture practice for C4ISR onto the high level conceptual outline of the recommended architecture practice as illustrated in Figure 3-3.

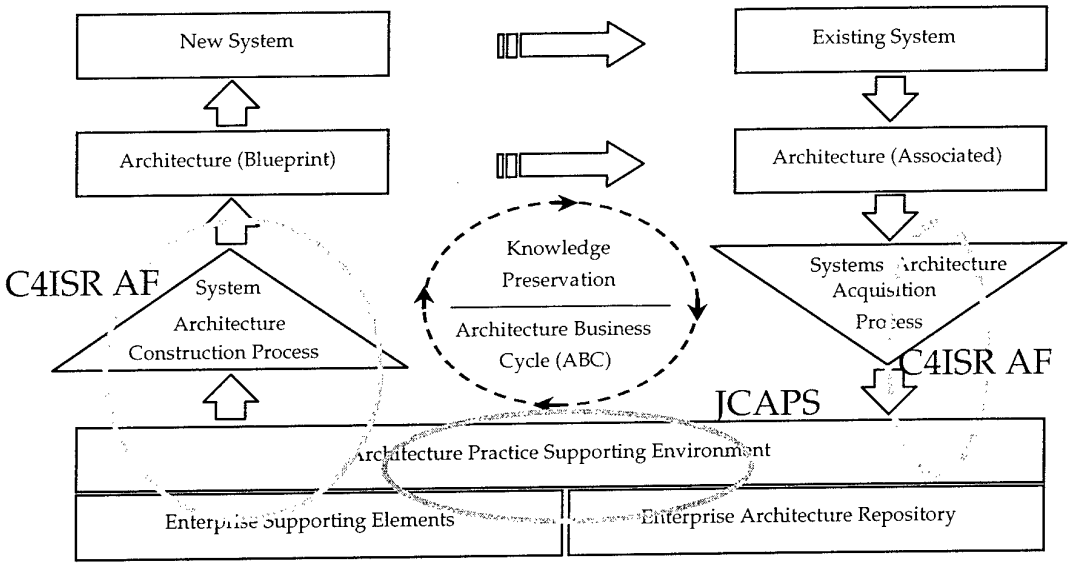

Figure 3-3. Coverage examination of US DoD's main architecture activities in C4ISR

Note that the US DoD did not choose to use any Enterprise Architecture approach developed by industry to either initialise its enterprise architecture development or guide its architecture practice as a whole. Due to the lack of definition of the DoD enterprise architecture and incompleteness of the specifications of JOA and JSA, it is difficult at present to draw an outline of the US DoD-wide enterprise architecture solution.

The US DoD's experience and achievements are certainly important for the ADO. Selective use of some US DoD achievement in architecture will not only reduce costs for the ADO but also ensure to a certain degree interoperability with the US DoD. It must be realised, however, that there are certain difficulties and risks if they are applied as total solutions to ADO's problems because of the differences in practice and culture between the two organisations.

4. An Historical Overview of ADO Architecture Practice

DSTO started work in architecture for the ADO about a decade ago with the work by Andrews et al (1989), which addressed an Integrated Australian Defence Communications Architecture. Sobolewski (1992) extended the research into the broader area of C3I, as a consequence of the growing awareness of the importance and complexity of C3I architectural issues. Based on the understanding at that time, a goal C3I architecture based on layering principles was proposed. Sobolewski's study suggested that a C3I System Development Architecture should be used as a base of "Evolutionary Acquisition", which includes "Evolutionary Development".

In 1996, the Distributed Systems Technology Centre CRC (DSTC) conducted a study sponsored by DSTO on issues in C3I architectures. Its Phase II report (DSTC, 1997) describes architecture issues with a broad coverage, ranging from technologies to methodologies. These included many of the US DoD's initiatives, but the focus was mainly on how distributed computing technologies, such as CORBA, could address certain issues.

With support from industry, the Battle Command Support Systems (BCSS) project used an architectural approach in 1998. This involved the use of The Open Group Architecture Framework (TOGAF), and was used mainly for technical architecture description and development.

From 1996 to 1998, the Information Architectures Group at DSTO conducted the C2 Support Study (Clothier, 1997 [a] and [b]), which investigated the IT capability required by the ADF under a variety of different operational deployment scenarios. The study pointed out that in order to better use information to support the defence capability, a defence information environment (DIE) should be developed and rationalised through use of an architectural approach.

Architectures are being developed, throughout defence and have been for a long time. However, these architectures are principally for and within individual projects. Currently, there is a trend toward individual projects that address larger and more complex development issues such as Joint System synthesis and simulation and joint systems for C4ISREW. Also, there are now systems with a broad coverage, such as JCSS and JISS.

Alison's paper (Alison, 1997) discusses the need for the development of an Enterprise Architecture Framework for C4ISR in the Australian military enterprise. The Enterprise Architecture presented is not an enterprise design, being rather a set of expressions that describe the relationships between the elements and tasks of a designated enterprise, and the information flows between them.

There are also a number of current DSTO research tasks that use the concept of architecture. These focus on different aspects of architecture use or development for various areas of the ADF, including the Battlespace Communications System (Land) Architecture (JNT99/141), the Core Communications Architecture (JNT99/150), C4ISR architecture simulation and assessment (JNT99/138), Joint C4ISREW SOS (JNT00/007) and Operational Architectures (JNT99/018). These tasks will generate various architecture products and architecture capabilities.

The Architecture Practice Study, of which this report is a part, was started in April 1999 to investigate architecture issues in an inclusive manner. By taking a different perspective, the study examines the broad context of architecture issues and related activities, and investigates their connections or interrelationships. This will allow a comprehensive and mature understanding of the practice to be obtained. Questions to be addressed include:

- What is the rationale behind the ADO's architecture practice?
- How can the architecture practice be successfully planned and managed?
- Which architecture products developed by other agencies or organisations (e.g. US DoD) can be adopted or tailored by the ADO, and how?
- Which architecture products must be developed by the ADO and how?
- How will the ADO's architecture practice evolve in the future?
- How should an environment be developed that is conducive to and supportive of enterprise architecture practice as part of the normal business process?
- How can an integrated architecture capability, including describing, visualising, simulating and evaluating, gradually be developed to support future C4ISR capability development?
- What current processes would be displaced if an enterprise architecture practice was to be adopted?

Learning from successful practices certainly will help the organisation to improve its own practice. Using the same architectural approach, such as the C4ISR Architecture Framework if applicable, however, does not have to mean the same architecture practice. Unlike a simple process, architecture practice cannot be easily copied from other organisations, since it is or has to be embedded in the culture of an organisation.

5. Requirements and Challenges of ADO IT Development Capability

Knowledge-based warfighting capability requires the ADO to be equipped with adequate information-based supporting capability. In order to meet the changing requirements of its core business, new IT capabilities will be developed and the existing capabilities will need to change or evolve as the organisation changes and technology advances.

As mentioned in Part 1, IT development capability is the power possessed by the organisation in knowing what and how to develop and support this IT capability, and implementing it efficiently and cost-effectively in its IT practice.

Developing adequate capability for IT development, which is the capability of the organisation to run its IT business, is a great challenge. Unlike certain organisations that can largely use external resources for developing their IT capability, the ADO has to develop its own IT development capability for its specific requirements, although elements of this capability can use IT development capabilities provided by industry.

In current IT practice, the IT development capability of the ADO is provided jointly by a number of players as shown in Figure 5-1, including:

- Defence Information Systems Group (DISG);
- Defence Acquisition Organisation (DAO);
- IT staff working in various parts of the ADO;
- DSTO;
- other members of the ADO; and
- Industry, both Australian and foreign.

Whether IT development capability is adequate for the needs of the organisation is determined not only by the amount of resources allocated, but also the way in which they are used.

The reality of evolutionary development of systems-of-systems shows that the requirements for an organisation's overall IT development capability differ from what is required for developing a single system. In the case of the ADO, the ability to use individual IT technologies, such as writing a piece of code in a particular language for a specific application, is certainly still an important aspect of the IT development capability. But this capability by itself is not enough. Indeed, the ADO's IT development capability is being challenged by various difficulties and problems encountered in evolutionary acquisition of C3I systems. For instance, it has often been observed that interoperability is not a purely technical issue. Any specific and well-defined system integration or data conversion can be quickly implemented through many different technology-dependent solutions. The difficulty of interoperability for the ADO, in fact, lies in achieving full specification of enterprise-wide interoperability requirements for the core business within the context of existing IT capability and future development.

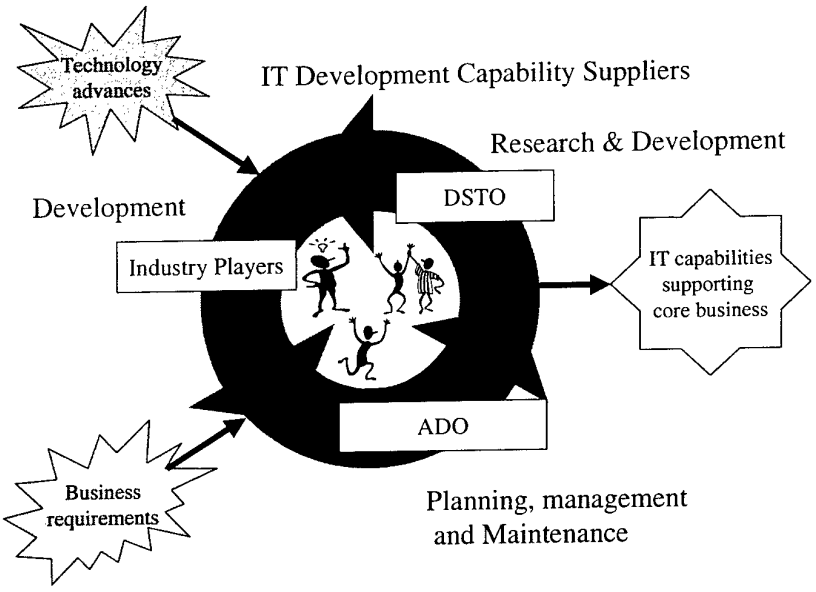

Figure 5-1. Providers of IT development capability for the ADO.

Another important issue observed in the current ADO IT development capability is that although people have realised the importance of organisational knowledge, the actual level of knowledge sharing, management and reuse is not satisfactory. The reasons for this are:

- There is no clearly defined organisational knowledge value chain;
- There is no well-developed common environment to support knowledge creation, management and reuse cross the organisation; and
- There has been no adequate organisational culture or defined process to ensure knowledge reuse and preservation.

For most organisations, including the US DoD and the ADO, the IT development capability has been built on a basis of individual system development, where each system has basically been developed independently. Individual capabilities in IT practice are *always* partly and individually demonstrated in those areas of the body of knowledge for C4ISR systems development mentioned in the previous section. The formation of the general IT development capability is basically "as it grows naturally" or "bottom-up" practice rather than through effective overall planning. One of the reasons for this is that since traditional software engineering approaches are designed mainly for "one at a time" system development projects. Such a development model leads to an IT development capability that is unable to successfully and effectively support SOS development in an evolutionary manner in the context of a large organisation.

The maturity of IT development capability is determined by the abilities in many different areas of IT practice, including business and technology planning, design, acquisition, implementation, maintenance and evolution. The ADO has demanding requirements in all these areas. Defining proper IT development capability for the ADO is thus important and should be considered by the senior leadership of the

organisation. Maturation of the IT development capability is critical to the success of its IT practice.

The following sections discuss how the ADO can and should improve the organisation's IT development capability through using the architecture practice shown in Figure 5-2.

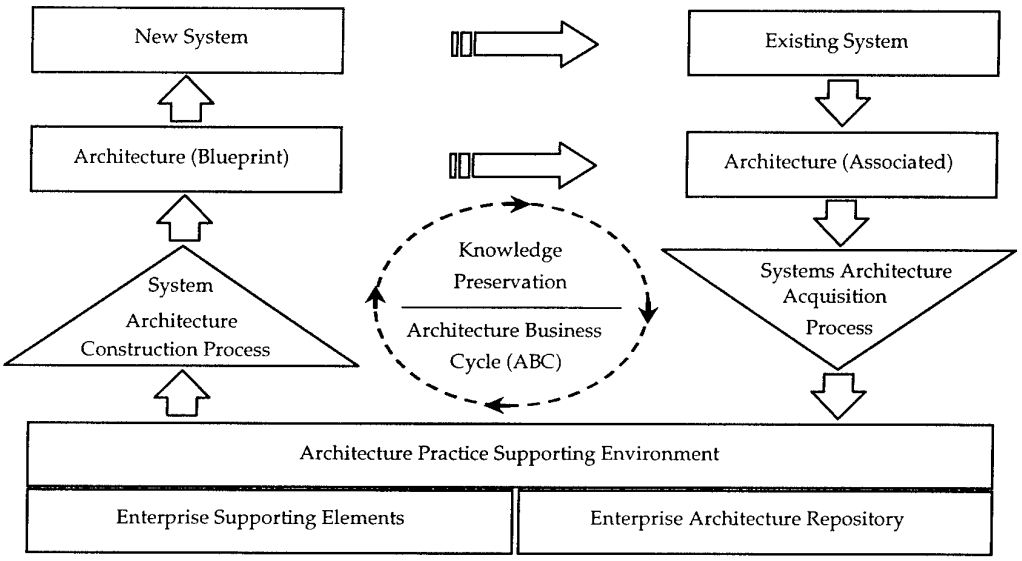

Figure 5-2. The recommended Architecture Practice.

6. Philosophy and Strategic Directions

The history and current activities in architecture across the ADO have shown a kind of architecture practice, which had no overall planning on the basis of any specific architecture practice model. If architecture is to be an important concept used by the organisation in its future development, this current practice must change in order to generate a more advanced and integrated architecture capability.

In the current IT practice of the ADO, apart from the daily business of IT as described in Section 2.1, there have been a number of important initiatives that require a common understanding about architecture practice, in particular in a SOS context.

- Defence Information Environment Board (DIEB)

  As the Defence Executive in IT, the DIEB has not only the responsibility but also the power and authority to determine what kind of IT development capability the ADO should develop for itself. Additionally, the DIEB requires adequate support in both thinking and measures for strategic decision making, as well as running the improved IT business in an innovative manner. Some studies and documents have mentioned or described certain concepts of architecture, such as the DIE Architecture and the DIE Architecture Framework. It is important now for the DIEB to reach clear definitions of these concepts and embed or link them properly into an overall development approach. Success in the design and development of the DIE will be determined by whether a high level IT development capability can been generated that specifically meets the requirements of the ADO.

- Development of Headquarters Australian Theatre (HQAST) and Deployable Joint Force Headquarters (DJFHQ)

  Development of various headquarters and command centres for the ADO requires an advanced capability in IT development that should be reliable, repeatable, efficient and cost-effective. This capability should ensure that the developed IT capabilities for the ADF adequately meet the needs of knowledge-based warfare, including providing a high level of interoperability. It must be noted that such IT development capability has not been generated yet, and is difficult to reach through the existing IT practice. Achieving the required capability will necessitate a significant change in culture and the methods of handling knowledge of Information Systems.

- TAKARI Program

  The Takari Program addresses one of today's greatest military challenges: dispelling the fog of war by collecting raw information, converting it into useable knowledge, and making it available to the commander who needs it, at the right time, in the right quantity and in the right format. Takari is not a single project. It is a program of separate, but related, research and development (R&D) projects running from 1996 to 2010, which are designed to help the ADO realise its vision of an integrated C3I/IO capability. Successful development of the integrated C3I/IO capability requires full establishment of the body of knowledge in all related areas of IT and C3I/IO.

  Achieving the aims and objectives of the Takari Program will test the R&D capability of DSTO. One of the critical parts of the DSTO capability is the IT

development capability. This can be demonstrated at different levels, including: invention and use of new technologies for CTDs; development of new concepts; and process innovation and methodologies to support both partial and global improvement to the IT development capability of the ADO.

Joint systems studies required by the ADF necessitate that DSTO develop adequate R&D capabilities for better SOS-related understanding, development, synthesis and modelling.

- The Knowledge management of the ADO

  In the concept paper on Knowledge Management (O'Neill, 1998), it was pointed out that "Defence is unlikely to achieve the Knowledge Edge without a considerable improvement in the organisation's ability to retain, build upon and exploit knowledge... Specifically, we must stop knowledge being lost when personnel depart or are posted".

  As one of the key business domains of Defence, IT practice itself is facing great challenges and requires innovation in knowledge management because of the symptoms mentioned in the introduction to the Part 1. Rationalised and well-planned organisation-wide architecture practice will lead to not only an environment for creation, management and evolution of organisational knowledge, but also to a cultural change in IT practice. This environment can effectively underpin the required improvement in the organisation's knowledge management capability.

Remark

In order to develop enterprise solutions in architecture for the ADO, it is important to properly define and specify the relationships between these efforts and their outcomes. Do we have an effective approach to relate these efforts and rationalise the relationships and connections between them? Can we use an approach such as the C4ISR architecture framework or META Group EAS to do this job?

The Architecture Practice Study reveals that any specific architecture framework or approach in most cases only partially addresses architecture issues of a large organisation, and has difficulties achieving satisfactory results individually. Therefore, what is required is a practice that allows the successful combination of different frameworks and approaches.

As pointed out by many DSTO studies, an overall development approach should be defined. The main challenge in defining such an approach is how we can organise these relevant activities into a rationalised and unified development framework.

Based on the comprehensive analysis of architecture and its context presented in Part 1, the architecture practice, as shown in Figure 5-2, recommended to the ADO has the following main objectives:

- To develop a framework to support examination and improvement of IT development capability;
- To engineer knowledge of information systems and covert it into reusable organisational assets;
- To achieve a framework to integrate and manage IT practice disciplines;

- To conduct the practice with clear strategic directions for defining, developing and managing architecture products, architecture construction processes and supporting environments; and
- To provide a platform for improved knowledge management in all defence business domains related to IT, including C4ISR.

The most important features of this architecture practice include:

- In terms of coverage, it includes architecture products, processes and tools/environments, and it is much broader and complete than any single architecture or architecture framework;
- It is based on architecture capability concepts that are above any specific architecture (product) development;
- It uses an architecture knowledge value chain to link or relate different aspects of architecture practice;
- It suggests that more attention be paid to architecture practice planning and management; and
- It suggests that all architecture developers need to clearly see the specific context in which they generate architecture — what system the architecture is associated with, which views it includes, which role (descriptive or supporting) it plays, how the role is implemented, how it can be used and reused over time across the organisation as an asset, and how the architecture can or should be developed.

When compared with the US DoD achievements, the ADO is facing the following strategic issues:

- How can architecture practice be successfully planned, managed and coordinated from both technical and management viewpoints?
- How can the ADO make use of architecture products developed by other agencies and organisations, e.g. US DoD?
- How can architecture practice help to achieve effective integration of related business areas in IT and capability development, which must fit the organisational culture of the ADO?
- What resources are required for improving ADO architecture practice and how should they be used?

The philosophy suggested by the Architecture Practice Study for the ADO is to use an integrated IT development capability model discussed in the next section to relate various aspects of architecture issues. This model can be used in combination with the recommended Architecture Practice Model shown in Figure 5-2 to generate overall guidance or enterprise solutions in architecture for the ADO.

7. An IT Development Capability Model

As discussed in Section 5, the IT sector and other relevant parties of the ADO, in conjunction with industry, are in an "enterprise" that provides IT capability for the organisation. It is observed that we have not defined and developed a suitable "business model" or working paradigm for our IT practice to efficiently and cost-effectively deliver the IT capability required. Therefore, it is not clear what kind of IT development capability the ADO should possess nor how it should operate in terms of generating deliverables and managing processes efficiently and cost-effectively.

As one of the main outcomes of this framework study, we propose a high-level working paradigm (or framework) of IT development capability for the ADO as shown in Figure 7-1. Through this paradigm, we study the ADO's needs in architecture practice in association with five components of IT development capability.

In order to ensure that at a high level integration of IT development capabilities in different areas is achievable, the effective generation, management and reuse of IT knowledge within the organisation become evidently critical. Such requirements in effectively engineering IT knowledge demand a well-defined, well-planned and implementable practice. Architecture Practice can be such a practice since its fundamental thinking and discipline are knowledge-based or knowledge-oriented. Whether the practice of managing knowledge can be successful largely depends on what kinds of architecture capabilities are designed and achieved in association with these components.

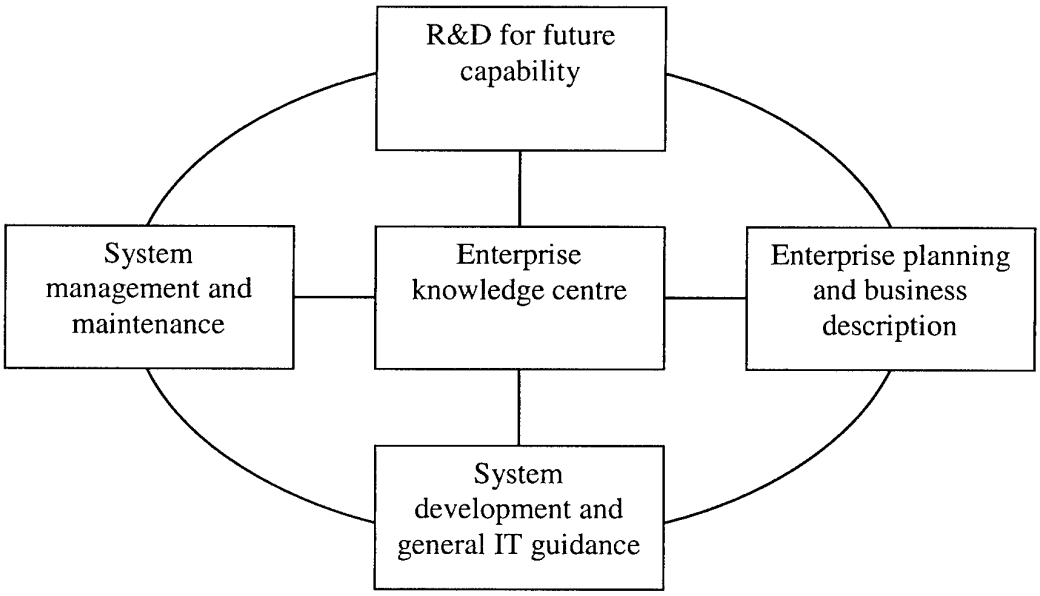

Figure 7-1. A working paradigm of IT development capability (ITDC) for the ADO

In such a paradigm, five components working together to deliver the required IT development capability for the ADO will be based on adequate support from various architecture capabilities.

It is certainly true that architecture itself is part of the IT development capability. Without proper use of architecture or mature architecture practice, the IT development capability cannot reach a satisfactory level for large organisations. Architecture can be indeed seen as a starting point for the improvement of the IT development capability.

It is suggested that the Senior Defence Executive, such as the DIEB and relevant agencies, can examine which and how capabilities in IT development or future organisation development have been generated and how mature they are.

7.1 Enterprise knowledge centre

An enterprise knowledge centre of IT products requires an enterprise architecture repository to capture knowledge regarding all existing systems within the organisation. This covers systems knowledge at the levels of operation, function, data, programming platforms and networking, and also what needs to be known for developing new systems. The repository should include an important element which is called *an Enterprise System Architecture or Systems Architecture* at the enterprise level. This element is currently being studied by a joint project between DSTO and Monash University, and will be the main resource of a well organised and integrated systems knowledge. This knowledge can be used for a variety of reference purposes in IT-related R&D, through provision of multiple views of systems.

Such a repository is defined and described in the recommend architecture practice, and is one of the main components in the Architecture Practice Supporting Environment (APSE).

Knowledge captured in the repository is extracted from various sources of systems knowledge, such as system development documents and the minds of system designers and developers. The extraction of knowledge is performed through conducting enterprise-wide domain engineering or a similar activity with adequate methodologies. Thus, such knowledge is updated and maintained as a living document.

Developing such a repository contributes directly to achieving an enterprise level systems architecture description. The repository is a critical step towards maturing the organisation's ability in knowledge management, since it will provide a means to stop the loss of organisational (systems) knowledge.

To provide the enterprise knowledge centre capability—architecture capabilities of knowledge extraction, publication and navigation—this component must be developed to serve as a key measure to realise knowledge into assets of the organisation and make effective reuse possible.

Apart from the enterprise system architecture that is an "as-is" architecture description, the enterprise architecture repository may also include other resources of knowledge associated with systems or used in new system development.

7.2 Research and development for future capability

The IT development capabilities within component include:

- Capability & Technology Demonstration (CTD) development;

- Enterprise data model analysis and synthesis;
- Enterprise information flow analysis;
- Information operation capability study;
- Enterprise interoperability requirements study;
- Studies of vendor-dependent technology, including system integration solutions (such as WWW, CORBA, Lotus Notes, middleware, messaging);
- Enterprise or joint systems behaviour simulation and performance evaluation; and
- Enterprise IT capability analysis.

Architecture products in various forms are not only main outcomes, but also inputs to these areas. Some of these products as outcomes are passed on to the capabilities of Enterprise Planning & Business Description and then to System Development, if they are approved for further study and development.

Studies on Information Operations (IO) / Electronic Warfare (EW) could also be considered under this capability.

Remark
No specific architecture framework has been developed for this kind of IT development capability as a whole. However, a unified testbed, such as EXC3ITE, is important since it can deliver CTDs in an integrated manner and with better efficiency and effectiveness. To successfully conduct activities in these areas, EXC3ITE needs to develop its R&D-oriented Architecture Practice, which should address specific needs of R&D and form as part of the Enterprise Architecture Practice.

7.3 Enterprise planning and business description

This part of the IT development capability performs plan generation and requirement specifications for future systems development, for example AST and DJFHQ development. Using architecture products or capabilities provided by other components in the model, planners can produce planning products, some of which can be architecture products, at both strategic and operational levels.

The architecture capabilities provided to this area include:

- Support for operational architecture generation

  Specific military operation models are created according to particular requirements. This framework is designed to enhance both conventional organisation planning processes and mission-oriented strategic level planning.

  Senior planning officers use the functions provided to this area to produce operational architectures, which have to not only meet business requirements, but also be based on the availability of resources and the existing IT capability of the organisation.

  Operational architecture development is a specific requirement of defence-business related architecture practice. Most architecture frameworks or approaches

introduced by industry players, including Zachman and MATE, cannot meet this requirement.

- Guidance for determination of IT capability

  Senior IT officers need to work with the planning officers in determining systems capability and information flow requirements for the operational architectures by using systems knowledge captured in the enterprise knowledge repository of IT products.

- Guidelines for conceptual construction of "Plug and Play" IT functions

  Senior IT officers produce specifications of system integration according to the guidelines, including the systems information exchange matrix and systems function traceability matrix.

  To support the warfighting needs of AST and DJFHQ, certain specific support is required to dynamically reconstruct and reconfigure systems, and to smooth systems support functions and information flows.

These capabilities, available through the APSE, can assist planning officers and IT officers to complete descriptions of operational architectures and specifications of required IT capability in accordance with architecture construction guidelines. With these architecture capabilities, the processes of future organisation development or reconstruction can be formalised to a certain extent. Architecture products produced in this area do not represent any physical systems unless they can be implemented through the capability of system development and under the IT general guidance.

Through using these architecture capabilities, we can ensure that IT capabilities (including "Plug and Play"), which support core businesses such as warfighting, can be planned successfully in a joint, global environment with high level interoperability.

7.4 System development and General IT guidance

Under this component of the proposed IT development capability, the ADO requires the architecture capabilities for supporting implementation, including:

- Reference architecture for system integration and "plug and play";
- Technical architecture framework (such as the US DoD JTA or META Group EWTA);
- Framework/methodology (such as the C4ISR AF) for developing architectures of new systems;
- Architecture-based methods for technology-dependent solution evaluation and selection;
- Architecture-based methods for system/project evaluation;
- Common Operating Environment / interoperability matrices;
- Engineering administration and project control framework; and
- Standards and policy.

These architecture capabilities work together through the APSE discussed in Section 9 to form the IT-oriented knowledge management environment for the daily business of DISG, DAO and other IT staff of the Department, and assure expected IT capabilities with quality and efficiency.

It is suggested that an architecture-based process framework for system/project evaluation be developed under this component, since it can assist the ADO in systematically analysing interrelationships and connections between a new system and other existing systems. Clear specifications of these interrelationships and connections should be reached before implementation commences. In the absence of this, many large systems/projects have been experiencing various difficulties and problems in systems integration and evolution.

Note that decisions made now and in the future in selection and design processes of technology-dependent solutions (for example, choosing a distributed computing platform, such as Web, DCE, CORBA, Java, Lotus Notes or Active X, for systems integration) are much more complicated and difficult than selecting a DBMS, OS or a programming language for applications development. Thus, a comprehensive architecture capability is highly desirable to help and formalise these processes and to reduce the possibility of failures caused by ignorance of some important factors.

7.5 System management and maintenance

When a system has been implemented, integrated and introduced into service, a framework is required as part of the IT development capability for its ongoing management, to ensure that it continues to meet requirements.

The capability required for this framework can be divided into the following main areas, which also require the use of architecture:

- Management and maintenance of current IT capability;
- Management of technology changes;
- Management of user and business changes;
- Managing the impact of system of systems changes;
- Acquisition of systems architecture at the enterprise level; and
- Configuration management, including dynamic "plug and play" management.

The first of these, the management and maintenance of current IT capability, represents the daily activities of ensuring that the IT capability in service continues to remain operational and effective. The rest of the areas are concerned with the understanding and management of change.

With all of these activities it is very important that the existing systems knowledge from all the other components of the IT development capability, as well as systems knowledge gathered within this framework (i.e. during the service life of a system), is readily available in a useful form. Without adequate architecture capabilities to ensure that this knowledge is maintained as an organisational asset, activities during the service life of a system are at best conducted inefficiently, and at worst lead to the severe degradation or loss of the IT capability that was supposed to be provided.

7.6 Summary

Using the philosophy of the architecture practice suggested earlier, this section uses a high level IT development capability model and combines it with the recommended architecture practice model, such that architecture relevance can serve as a basis for integration of architecture capabilities. As a result of this integration, an integrated architecture capability can be developed with the support of an enterprise architecture practice supporting environment (APSE).

Such an **Integrated Architecture capability** consists of the following components:

- Architecture resources that include various architecture products both descriptive and supporting developed on the basis of a well-established architecture lexicon;
- Architecture-based functions/services, including generic and specific, which can realise effective use of architecture for various purposes in all aspects of future organisation development;
- Well-defined and well-coordinated architecture development processes guided under certain methodologies;
- An Architecture Practice Supporting Environment, as discussed in Section 9, which provides not only solutions for architecture resources management, but also a unified and integrated platform for architecture-based functions/services development.

To clarify possible confusion in the relationship between such an IT development capability oriented architecture practice philosophy and other architecture frameworks or approaches, it is worth noting the following points:

1. The idea of using the IT development capability in combination with the recommended architecture practice model differs from use of a particular methodology, such as the C4ISR Architecture Framework. We started with identifying the IT development capabilities required by the ADO, in particular in supporting evolutionary development of C3I systems. This shows specific requirements of architecture for the ADO, which are much broader than what existing architecture frameworks can cover individually.

   This idea does not, however, reject use of those frameworks or approaches if they are proved to fit well into the paradigm and the ADO's needs. Indeed, it helps us to effectively use them and to further develop or mature them within the context of the IT development capability for the ADO.

2. The analysis of ADO IT development capability shows the importance of using an architecture knowledge value chain for the architecture practice that can provide a context or framework of use of multiple architecture frameworks or approaches within the organisation. In other words, it helps us to relate different architecture frameworks that cover different aspects in architecture practice.

3. The paradigm suggested here is just a starting point of a long-term effort to mature the organisation's IT development capability through using architecture. Decisions as to whether the ADO should adopt such a paradigm must be made by an

authorised agency, such as the DIEB, and endorsed at a high level. Planning and coordination of development of architecture capabilities requires a dedicated working group with representatives from relevant parties within the organisation, which is similar to the C4ISR Architecture Working Group (AWG) that produced the C4ISR architecture framework for US DoD.

4. This paradigm suggests that a unified top-down framework be used for planning the IT development capability. The advantages of using this framework are to:

- Define a fundamental business model of IT practice, including architecture practice, for the organisation;
- Achieve effective architecture practice management;
- Clearly identify weaknesses or gaps in the IT development capability;
- Enable R&D activities to be carried out in a well-planned development context;
- Facilitate flexibility in selection of methodologies and change or evolution of concepts and technology;
- Enable individual concepts, techniques and systems to evolve smoothly and consistently with other relevant components; and
- Provide senior officers with a better understanding of the business of the DIE and adequate support in planning and reviewing projects.

8. Chief Information Architect (CIA) and Architecture Review Board (ARB)

With the understanding of the relationship between the IT development capability and architecture practice discussed in the previous section, this section discusses how the expected architecture practice can be planned and implemented within the ADO by the CIA and the ARB.

8.1 Main interests of CIA and ARB

Planning and managing architecture practice is the key business of the Chief Information Architect and the Architecture Review Board that was formed under the recommendations of the DIEB.

In practice, there are many teams working in different areas on the development of individual architecture products. In order to manage enterprise-wide architecture practice, the CIA and ARB should oversee what architecture products have been or will be developed, through which processes and using which methodologies, and how they are maintained and used over time.

Thus, it should be the responsibility of the CIA and ARB to develop and manage a business model of the enterprise-wide architecture practice, to make decisions on the generation of architecture capabilities and review outcomes, and to make sure that their integration can be achieved. Figure 8-1 expresses the three aspects of the architecture practice that the CIA and ARB must control.

The ADO has developed architectures and therefore had a form of architecture practice. This will continue even without guidance from the CIA and the ARB. The difference that the CIA and the ARB can make to the future architecture development is a disciplined architecture practice with a distinctive outcome of an integrated architecture capability.

8.2 Main activities under the CIA and ARB

Since the ARB was formed, there have been many reports on the ongoing progress of various activities made at its monthly meetings. To the authors' understanding, the main progress in the development of architecture products within the ADO can be classified into four main subsets at the enterprise level as shown in Figure 8-2, namely, *Operational Architecture subset, Systems Architecture subset, Technical Architecture subset* and *Concept Technology Demonstrators* (CTDs).

The main purposes for grouping various architecture products and capabilities developed within the ADO into these four subsets are: 1) to create a framework for architecture product management at the enterprise level; 2) to present all relevant products in a context that can be used to compare various architectural approaches or enterprise architecture frameworks (such as the C4ISR AF and Meta Group EWTA or EAS); and 3) to see precisely how architectures can be related to each other when architecture production processes are introduced.

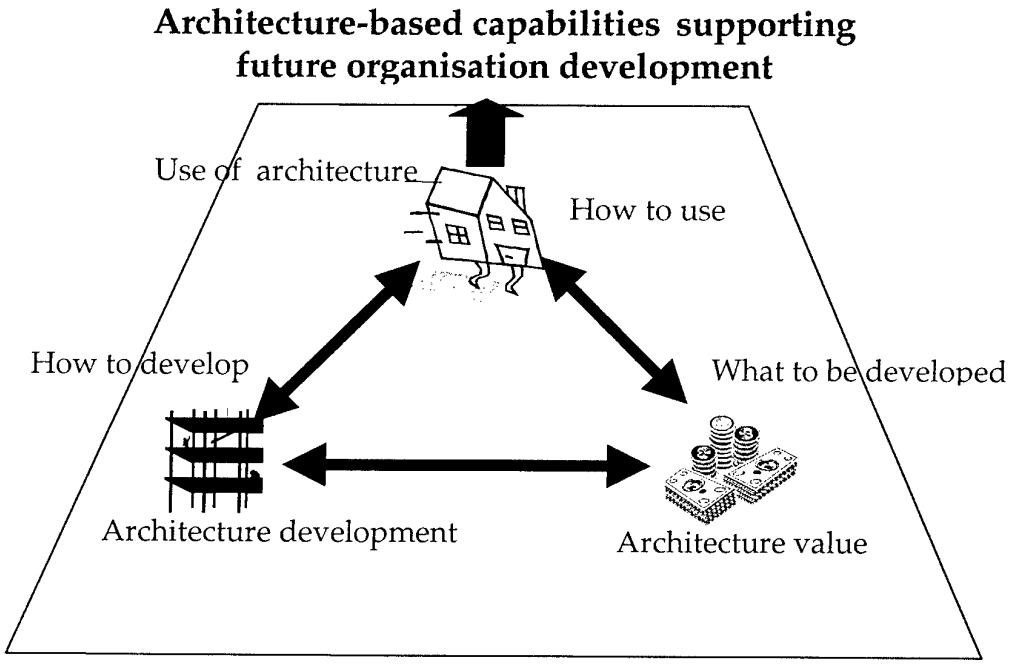

Figure 8-1. Aspects the CIA and ARB must control in architecture practice.

All supporting/guiding architecture products developed in these subsets can be seen as the enterprise supporting elements of the ADO APSE.

Each of these subsets should include a number of defined elements that play different roles in future architecture development. If necessary, certain architecture frameworks or approaches can be used to guide the development of these subsets. For example, the approach used in developing TAFIM by US DoD or EWTA by META Group can be used to guide development of the Technical Architecture subset.

Developing the operational architecture subset is a critical task and one that is not familiar to both defence and IT communities. This subset will include a number of architecture products, such as Task Lists, Military Response Options, Business /Operational (day-to-day) architectures of the Services and campaign planning guidelines. These products are used in operation planning for either the joint or single service; and play supporting roles in developing future operational architectures at all levels for various mission-oriented purposes.

It is noted that in order to realise the value of architecture, the development of architecture products in these subsets should not be isolated from their application processes. Without knowing how they can be used and planning to implement that, the value and significance of architecture would be dramatically reduced. Ill-planned development of architecture products in any of these subsets may not only cause confusion, but also generate products that may not be able to be used effectively.

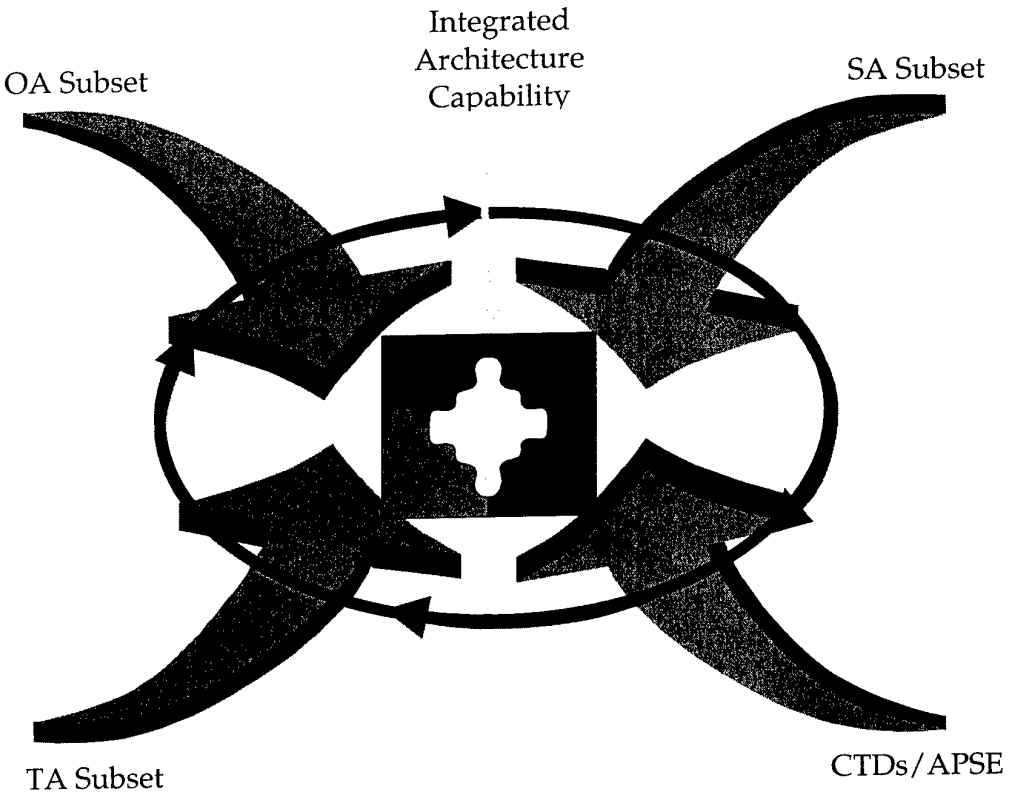

Figure 8-2. An integrated architecture capability.

8.3 Main views for managing architecture practice

Three main views are suggested to assist the CIA and the ARB in managing the architecture practice of the ADO, with these being, *Architecture Products View*, *Process/Methodology View* and *Tools/Environment View*.

- **Architecture Product View** defines which sets of architecture products should be developed and clarifies use of terminology.
- **Process/Methodology View** addresses how those products should be developed through which processes and methodologies.
- **Tool/Environment View** provides solutions and support for physical development and management of architecture products over time, and realisation and integration of architecture-based capabilities.

Through use of the three views, the CIA and ARB can see any architecture product or architectural framework as an element in the whole practice and have the ability to deal with the complexity of multiple frameworks based practice, as discussed in a subsequent section. Note that without a broad and deep understanding of architecture issues, it can easily be believed that developing a certain architecture product(s), often called the enterprise architecture(s), could solve all issues in architecture for the ADO. Such a belief could become a barrier that restricts the organisation from looking at much broader architecture issues for achieving the full benefits of architecture practice.

Therefore, the architecture practice thinking is one level above most existing architecture frameworks or approaches. This is why the well-planned and well-organised architecture practice can accommodate multiple architecture frameworks if necessary.

Remark: The main advantages of using this three-view-based management strategy are: 1) reducing confusion in use of different terminologies; 2) providing clear context management of the practice in an inclusive manner; 3) being able to accommodate multiple frameworks for different architecture production (as discussed in Section 10); and 4) a focus on improved general IT development capability rather than development of any single product.

A management framework for ADO architecture practice can be defined on the basis of these three views.

8.4 Survey of ADO architecture products

As an important representation of system knowledge, as discussed in the Part 1 of the report, architecture is a concept that has six main attributes determining its context in multiple dimensions, as shown in Figure 8-3. It is these attributes that create complicated relationships amongst various architectures (products). Therefore, to fully understand the context of an architecture product, including its roles, relations to others and ways to use it, the clarification of these attributes for each architecture product is important.

As part of the architecture practice study, DSTO intends to conduct a survey of architecture products in the ADO. Such a survey will help gain an understanding about the current state of architecture practice across the organisation. It is also an important step towards establishment of coordinated architecture data management across the organisation, and will provide a basis for effective evaluation and rationalisation of architecture practice.

The aim of the survey is to capture information about architecture products in a methodology-neutral manner. No strict definition of architecture will be suggested by the survey, although some explanation of certain terms will be necessary. The survey will be designed to capture important attributes of architecture products and architecture related products.

The survey will initially be conducted in a limited fashion with a narrow scope, before it is more widely conducted across the organisation.

It is expected that the survey will provide information about what architecture products have been developed or planned, what roles each architecture product plays, and how the architecture products have been used, as well as what methods and tools have been used in their development. Other information useful for architecture product management will also be collected.

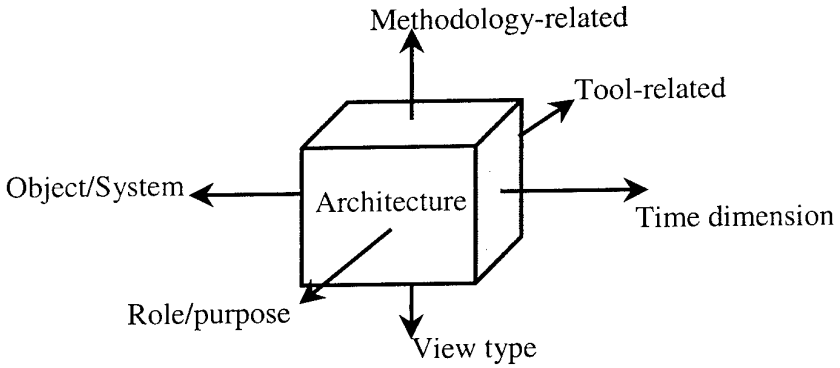

Figure 8-3. Architecture attributes in multiple dimensions.

9. Architecture Practice Supporting Environment for the ADO

9.1 What is it going to achieve?

In the recommended architecture practice discussed in Part 1 of the Phase I report, the architecture practice supporting environment (APSE) is one of the key components defined. It is through this component that various architecture-based capabilities can be broadly presented in an integrated manner to a wide community for knowledge sharing and reuse and supporting future organisation development. It is through this component that the CIA and ARB can successfully manage the architecture practice and bring healthy cultural changes to Defence through creating a workable architecture environment.

9.2 Design Principles of the APSE

Development of the APSE is a key to achieving an integrated architecture-based capability for the ADO as a whole. While capabilities associated with various architecture products have been developed, an integrated APSE is yet to be addressed. The development of this capability should be seen as one of the main tasks of the Architecture Review Board or related architecture working groups of the Department. The design principles of the APSE for the ADO can be discussed in the following main aspects.

- **Requirements studies.** The working paradigm of IT development capability shown in Figure 7-1 can be used as the starting point to study requirements for this environment. Various use scenarios and potential architecture-based capabilities to be developed can help outline both generic and specific functions/capabilities of the APSE.
- **Composition.** The requirements studies can help determine which elements should be included in the environment.
- **Relation to existing tools and capabilities.** Since the APSE will serve as a unified platform for generation, management, evolution and use of architecture, integration of the APSE and the tools used in architecture development and architecture repository management are two main issues that need to be addressed when the APSE is developed.
- **Architecture management.** Solutions for enterprise-wide architecture products/data management should be designed and implemented through development of the APSE. There are two areas where adequate solutions must be addressed: 1) corporate supporting architecture product or ESE management; and 2) systems architecture at the enterprise level, also called enterprise system architecture.

More detailed investigation into the design issues of the APSE will be addressed in a separate report of the Architecture Practice Study.

9.3 APSE development by the US DoD

When the C4ISR Architecture Framework was introduced, a number of reference elements or common building blocks (JTA, JOA, LISI, CADM, SHADE, UJTL, TRM and DDDS) were mentioned as supporting references. These formed an initial set of the enterprise supporting elements for the architecture practice of the US DoD. Indeed, any other architecture approaches or frameworks, or architecture-related activities should also be able to use them.

Though US DoD has not yet formally identified any systems developed in association with its architecture practice as its architecture practice supporting environment (APSE), the development of the Joint C4ISR Architecture Planning/Analysis System (JCAPS) under the C4ISR Architecture Working Group of OASD (C3I) is an indication that the US DoD intends to have its architecture-based capabilities integrated, and to deliver them to various users across broad areas of the US DoD.

9.4 ADO's APSE

The main purpose of pursuing architecture practice for the ADO is to improve IT development capability across the organisation as an integrated whole. It is intended that this will be realised by achieving a high-level knowledge practice through engineering IT systems knowledge and integrating it with warfighting business knowledge. The capability is by its nature provided by the coordinated efforts of often traditionally disparate parts of the organisation, which together comprise all the related areas where the various architecture activities occur. This generates a diversity of architecture products or supporting products as architecture knowledge resources. The accessibility of these products is important and is one of the key factors that determines the level of architecture practice maturity. Successful use of these products realises their value. To achieve these aims the practice needs to cover the whole spectrum from resource generation through to service provision within the practice community.

As discussed in Part 1, the solution for effective management and use of architecture knowledge resources is to develop an Architecture Practice Supporting Environment for the ADO.

Figure 9-1 shows the recommended APSE for the ADO, which includes three main sectors, namely, *architecture resources, shared facilities* and *architecture services*.

- **Architecture resources** are a collection of developed architectures including both supporting/guiding and descriptive products that can be used across the organisation. Building up the architecture resources is the responsibility of all relevant parties.
- **Shared facilities** are all necessary functions to generate, manage and use architectures, including those supports necessary for enterprise-wide architecture knowledge sharing, such as repository and web-based access.
- **Architecture services** are those architecture capabilities, based on the shared facilities, developed specifically for different business domains.

In a disciplined and well-organised architecture practice, architecture capabilities development for different purposes, such architecture-based simulation, modelling,

planning and evaluation, can greatly benefit from developed and available architecture resources and shared facilities and can be carried out in an integrated manner. Consequently, these capabilities can be more practically and efficiently used by relevant parties / developers or users of APSE in supporting improvement of ADO's ITCD.

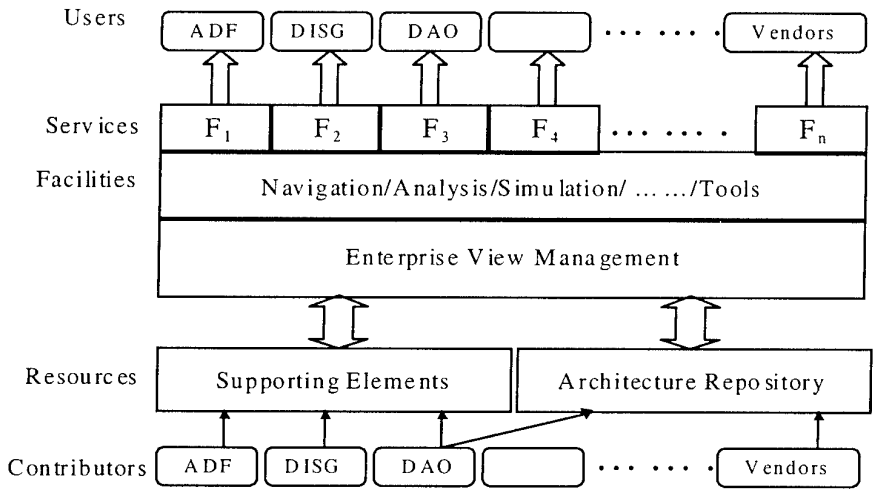

Figure 9-1. The recommended APSE for the ADO.

9.5 ADO's systems architecture — a hole to be filled

Most architectures of individual systems are developed at a project level by different teams using different methodologies. It has been difficult to see the architecture of systems of systems or *systems architecture* at the enterprise level. If an enterprise needs to be seen as a "big" system, there are unsolved questions regarding its *enterprise system architecture*: 1) do we need this architecture; 2) which role (blueprint or current picture) this architecture plays; 3) when the architecture should and can be developed; 4) whether it is updated; 5) who is responsible for development and maintenance of such an architecture.

As discussed in Part 1 of this report, developing systems architecture at the enterprise level is important for evolutionary acquisition of SOS, but challenging because there has been no existing solution and no one has taken responsibility for it. This is a similar task to the development of JSA in the US DoD. The Architecture Practice Study task suggests that such an systems architecture be developed as part of an architecture repository, and has started a joint research project with Monash University to address:

- A study, including literature reviews and theoretical findings, of the concept of an enterprise systems architecture repository combined with the real world practice of the ADO;
- Principles of engineering and using information systems architecture knowledge;

- A framework of design for a repository that meets the requirements in knowledge representation and management functions required; and
- Notations or descriptive languages used in deriving, refining and integrating systems architecture knowledge and maintaining it in a repository.

Research issues that need to be addressed fall mainly in two related sectors.

1. Requirements study
   To study requirements for an architecture repository, the project will investigate the following aspects:
- Which information systems knowledge should be captured;
- What purposes the knowledge is used for;
- What functions an architecture repository should be provided with and in what application scenarios; and
- How the architecture repository is related to other elements defined in the architecture practice supporting environment.

2. Design issues
   To work towards designing such a repository, the project will have research focuses on certain technical concerns and their theoretical underpinning, including:
- A framework or organisation structure for the repository;
- Proper notations or descriptive languages used to capture and interrelate systems architecture knowledge for storage in the repository;
- Management of architecture views to assure sufficient functions and flexibility for use of the knowledge;
- Ability to support architecture analysis through use of the repository; and
- Relation to and integration with Computer Aided Software Engineering (CASE) tools.

The progress of the ADO's systems architecture will be reported separately.

10. Multiple Frameworks Based Practice

As discussed in previous sections, a total solution for the ADO enterprise-wide architecture practice can be studied through using the concepts of architecture practice and IT development capability.

Distinguishing this total solution from the concept of the enterprise architecture is important. It was pointed out earlier that the enterprise architecture suggested by many architectural approaches is only part of the total solution. It is an important one but it must be clearly defined in terms of the roles (a descriptive product or a supporting product) it can play in the whole architecture practice.

10.1 Using the term "Enterprise Architecture" with caution

The term "Enterprise Architecture" has been used in different contexts by many teams and projects within the ADO, which are mainly associated with the use of different methodologies or in the discussion of certain ADO documents. These include:

- Use associated with the Zachman Framework
- Use associated with the META Group's EAS and EWTA
- Use associated with the C4ISR AF
- Use associated with RM-ODP
- Use associated with the DIE Architecture Framework
- Use associated with specific sub-domains of the ADO

According to these different uses of the concept, we see the so-called enterprise architecture as one of the following products:

- One or a set of architectures, such as a standard-based Technical Architecture, which play mainly supporting or guiding roles for enterprise wide IT practice;
- An architecture description of the enterprise, which can be either "as-is" or "to-be"; or
- A technology-dependent enterprise design solution.

Strategically, therefore, the ADO needs to first decide its own definition of enterprise architecture. If its definition is consistent with any use in the above cases, this architecture should then be treated as a single product or a set of elements within the enterprise architecture practice.

Whether a specific area or part of the ADO can be seen as an enterprise is a debatable issue. It is important, however, to make the context clear when the term, "enterprise architecture", is used.

Remark

A total enterprise architecture solution for the ADO should therefore have the following features:

- Dealing with the result of evolutionary development of systems of systems (SOS);
- Providing an understanding of SOS rather than a single design solution;
- Generating an evolving and valuable asset of the organisation knowledge, in particular C4ISR operations knowledge;
- Developing a set of principles and guidelines for future system architecture development;
- Defining a set of processes for architecture production, management and evolution;
- Developing a knowledge environment for improved systems knowledge communications; and
- Developing a supporting environment, APSE, for the formation of an integrated architecture capability.

The relationship between the enterprise architecture as suggested by either META Group or the Zachman's Framework and the architecture practice philosophy is discussed in Part 1 of this report. It is worthwhile to recall here that the enterprise architecture should be one of the important elements in the architecture practice and it cannot achieve the full potential of the architecture practice without integration with other architecture-related activities. Suitability of an architectural approach for a specific organisation must be properly examined before use.

10.2 Evaluation and selection of architecture frameworks

It is strongly suggested that any important architecture development should follow certain guidance in an architecture framework or methodology. The ADO's architecture practice requires guidance for its three main subsets, namely, Operational Architecture subset, Systems Architecture subset and Technical Architecture subset.

After familiarisation with various architecture frameworks, the ARB needs to make decisions on which frameworks should be used for development of which architectures.

Since it is not an easy task, developing a new framework for specific needs in certain areas of the ADO is necessary only if no existing framework is suitable. Risks involved in such development can be reduced if a solid understanding of the existing and whole context of the architecture practice can be reached.

ADO's broad interests in architecture require an architecture practice thinking based on multiple architecture frameworks. Multiple architecture frameworks can be jointly used in different areas of the ADO's practice and can be beneficial to each other if the practice is well planned and well coordinated.

An important issue in multiple-framework based practice coordination is the planning and selection of an appropriate set of enterprise-wide supporting elements. These can be either be defined in an architecture framework used or developed independently as far as they can play the necessary supporting/guiding roles in a complementary manner in future architecture development. For example, some supporting elements, which are similar to the common reference blocks of the C4ISR AF, and certain domain architectures suggested by META EAS can all be chosen as the enterprise-wide supporting elements if the ADO decides to use both approaches.

11. Architecture Product Planning and Management

11.1 Architecture product planning

Because of their diversity and multiple-dimensional attributes, values of different architecture products vary and change over time. One of the main principles of architecture practice is to optimise architecture production and maximise the value of developed architectures.

Apart from the six main attributes of each architecture that create the high complexity of architecture practice (as discussed earlier), it is observed by the architecture practice study that underperformance or failure in architecture development is often caused by the following factors:

- Over-estimating the value of a specific architecture product;
- Insufficient use of developed architectures;
- Short lifecycle of an architecture product, in particular for those future architectures if they are technology dependent;
- Ill-defined context of the architecture business cycle (ABC) for a specific architecture from its definition, view type, roles and development method to use;
- Lack of coordination among relevant architecture activities and integration of ABCs of relevant architecture products; and
- Inappropriate decision making in architecture, which largely depends on personal understanding and preference of individual developers, rather than being examined and approved by authorised agencies.

In order to improve the performance of architecture practice, therefore, it is necessary to establish the formal process of architecture product planning. Without this planning, effective architecture product management cannot be carried out, and the success of the whole architecture practice will be compromised.

Successful architecture product planning relies on the establishment of a ***consistent architecture value system*** across the organisation to clarify the context and value of architecture.

11.2 System knowledge generation and management

Knowledge issues in IT practice are complicated and demand better solutions. The proposed ADO APSE has the potential to become a knowledge management environment for architecture practice, which could help the organisation to significantly improve production, use and management of system knowledge in IT practice.

To support the re-use of knowledge, therefore, the recommended architecture practice shown in Figure 5-2 has the following features:

- Consideration of all R&D activities as in a whole process which needs internal coordination to transform knowledge (various architecture) products and preserve them over time;
- Separating acquisition of SOS architecture (of existing systems) or systems architecture from conventional design process and making it an independent task that obtains and maintains the IT knowledge in the repository;
- Taking the viewpoint of product management in architecture practice, architecture production plans need to be made against the three subsets accordingly in order to ensure they can be covered when related processes are defined and developed.

11.3 Coordination of architecture issues

11.3.1 Framework coordination

US DoD's experience in architecture (USGAO, 1998) shows that coordination among concepts, products, methodologies and working groups is an extremely difficult and continuous task. This is because all these aspects are changing and evolving in parallel over time. An overall control mechanism is very desirable, but difficult to achieve.

Architecture framework coordination is not seen as an internal issue of any architecture framework, but is definitely an issue for the architecture practice, in particular when it is a multi-framework based practice. The main objectives of the coordination are:

- Smoothness in system knowledge generation and management processes
- Representation consistency in terminology and graphical presentation
- Knowledge communication support
- Accessibility to architecture products
- Traceability of architecture production
- Completeness of systems knowledge
- Product transformation support

11.3.2 Architecture Business Cycle (ABC) coordination and management

Effective use and reuse of architecture products demands not only accessibility to the products, but also their evolutionary and extendable ABCs. Each architecture product has its own ABC. The **Integrated architecture product cycle** illustrated in Figure 5-2 forms an architecture knowledge value chain and shows how individual ABCs of architecture products depend on each other and how knowledge value can be realised and preserved in practice.

Effective planning and management for supporting products are extremely important measures to ensure a well defined and organised overall architecture-based approach for future system development within the ADO.

From the experience of US DoD it is observed that such an approach is not well defined, since its supporting elements have not been fully developed and a unified

supporting environment is yet to be developed. Without the coordination, and due to lack of understanding of architecture practice, the products are mainly developed based on the understandings and preferences of individuals. In other words, there is no guarantee that the product could fit together well when the practice becomes more mature. Consequently, dramatic changes or even redesign may become necessary during the course of evolution.

Therefore, a lot of difficulties and challenges have resulted from a lack of coordination when the products are developed. In the current practice of the ADO, most of its products have not yet been developed. Thus, effective architecture product management and coordination across those subsets should be considered and organised to decide which supporting or descriptive products are needed and how they should be developed.

12. Implementation strategies

Architecture practice is an ongoing effort of the organisation based on various activities across the whole organisation. This section briefly describes the relevance and responsibilities of the main areas of the ADO which have important roles to play in architecture practice.

12.1 Capability Development

The planning of the ADO's architecture practice is best performed by those responsible for Capability Development for the following reasons:

- Information-based capability is part of the defence capability for knowledge warfare and is a key to success. An inability to efficiently and cost-effectively deliver an advanced information-based capability for the ADF is challenging the organisation's capability in its future development.
- Planning and improving the IT development capability for the ADO to better operate its IT business and improve the capability of future organisation development is a task of Capability Development, although it is not a traditional one.

In order to plan and start enterprise-wide architecture practice within the ADO, strategic decisions for the whole organisation need to be made. Capability Development has the responsibility for making these decisions on the organisation's behalf in the following areas:

- Strategic directions and scope of architecture practice
- Business model of the architecture practice
- Organisation structures of the practice
- Management and coordination of architecture-related activities
- Prioritising initiatives and evaluating the existing practice
- Making other relevant parties aware of their responsibilities in architecture practice

It is suggested that Capability Development and the DIEB should have architecture practice thinking at a level that is above developing individual architecture products or capabilities. Its main objective is to make sure these individual products and capabilities can be integrated and form a unified architecture-based knowledge platform to support future organisation development.

12.2 Defence Materiel Organisation (DMO)

The defence information-based capabilities used in operations are predominantly developed by industry and acquired through the DMO. The history of the acquisition process of many software-intensive systems has shown that there are great challenges for the ADO, and in particular the DMO. The issue is how to efficiently and cost-effectively produce advanced information-based capabilities with high-level interoperability through applying the latest technologies.

Enterprise wide architecture practice can help the DMO in process innovation and cultural change of the acquisition process through improved knowledge acquisition capability in all stages of the development and delivery of a system. This includes the following:

- The inclusion of knowledge or architecture acquisition in the acquisition process;
- Making industry contractors aware of the ADO's architecture practice and requiring them to follow it accordingly in their practice; and
- Using developed architecture products in all relevant stages of development projects

The main responsibilities of the DMO in architecture practice include:

- To produce the vendor architecture practice guidance in accordance with the ADO's architecture practice, in order to ensure vendors follow the practice of the ADO;
- To support implementation of knowledge acquisition as part of acquisition business;
- To ensure that those involved in the processes of project approval and budgeting make best use of architecture to reduce costs and avoid failures in IT development; and
- To assist in the acquisition of the enterprise systems architecture, if this is another agency's responsibility.

12.3 Defence Information Systems Group (DISG)

DISG's interests in architecture focuses mainly on certain enterprise architecture products, such as technical architecture (or framework), Network communications architecture, Common Operating Environment (COE) and various standards. Therefore, DISG is one of the main agencies that generates important supporting elements for the architecture practice supporting environment (APSE) of the ADO. To make its products widely accessible to the whole defence community, they should be delivered as part of the APSE.

12.4 Australian Defence Force (ADF)

In architecture practice, the main responsibilities of the ADF are development of the operational architecture subset, which includes:

- The development of operational architectures (see the definition in the C4ISR AF, which is mainly suitable for operation description at a level of military mission planning) and other architecture products associated as either references or supporting elements for all levels and scenarios of military operations. Included here are such things as Military Response Options (MROs), task lists and other rule-based references used to support campaign and mission planning. This will lead to more effective generation, management and reuse of organisational knowledge.

- The definition and standardisation of the development processes for operational architectures for important areas of the ADF, such as HQAST and other strategic and operational level headquarters.
- Collaboration with other agencies (such as DSTO) to understand the ADF's special requirements in architecture practice, for example, those related to supporting military campaigns, and also specific IT development capabilities that are required, such simulation and modelling.

The operational areas of the ADF will be one of the main beneficiaries of the defence wide architecture practice, since their future development will be supported through use of architecture-based capabilities. These capabilities should be designed to meet the requirements for addressing the features of future warfare, such as network-centric warfare, and supporting "sensor-to-shooter" information-based solution optimisation. They should be delivered through improved solutions for the generation, management and evolution of military operations knowledge.

Using architecture for the description of military operation concepts will make it possible to better align IT development with business change. Operational architecture development is a new area for both military and IT staff and requires joint efforts to make it become part of the ADO architecture practice. For similar reasons to those for architecture practice overall, adequate high level planning and scheduling for operational architecture development is necessary in order to ensure consistency in use of terminology and techniques amongst the various activities that may generate operational architectures or relevant products for different parts of the ADF.

Operational architecture development for the ADF is not about development of a single product. It should indeed involve a set of relevant architecture products, which can be either descriptive or supporting products, and a set of processes, which are designed for the generation and use of operational architectures for different areas of the ADF.

In the recommended architecture practice model, developing an operational architecture for a new system or a specific mission is seen as part of the system architecture construction process. The development of various supporting elements for operational architecture generation is not included in the model. In the ADO' APSE shown in Figure 9-1, however, we expect different agencies to make their contributions to relevant areas of architecture resources that includes those supporting elements for operational architecture development.

To the authors' somewhat limited understanding to date, it seems necessary to further decompose the task in the area of operational architecture development into sub-tasks. Operation architectures/concepts should be developed differently in certain different domains (Land, Air, Maritime or Joint), levels (strategic, operational or tactical) and scenarios (event-driven). Coordination among these sub-tasks is required and is better addressed using architecture practice thinking.

The C4ISR AF was introduced by the US DoD to guide development of all C4ISR architectures including operational architectures. The ADF needs to first look at whether this approach is suitable for the ADF and whether it can be used by the ADF after appropriate modification.

If it is shown that the C4ISR AF (Version 3 is being developed) is not suitable for the ADF, then a decision should be made to develop either a unified operational architecture development approach for the whole ADF, or selected approaches for different parts.

Through the ADO's APSE, the integrated architecture capability for the C4ISR domain should include:

- Architecture products both descriptive and supporting used as knowledge resources to develop operational architectures for all areas and levels of the ADF; and
- Architecture-based functions/services for both generic purposes (such as creation, navigation, publication, visualisation of architecture) and specific purposes (such as architecture-based planning, simulation, and performance evaluation of SOS).

12.5 DSTO

Architecture practice is an emerging discipline and involves many challenges in research and development. This discipline is related to many R&D areas of DSTO, including information architectures, systems engineering, software engineering, systems simulation and assessment, systems of systems, military operations studies, information operations and various information-based capability developments where architecture products are either generated or used.

Along with the cultural change of the ADO through use of architecture to support its future development, it is also appropriate for DSTO to consider how its research culture and capability can be improved based on architecture in order to provide better advice and services to the ADO. Opportunities for improvement lie in the following aspects:

- Consideration of architecture as a capability that can be delivered to clients through well-developed architecture practice;
- To use architecture practice as a basis for integration of relevant DSTO R&D outcomes, in particular through making contributions to the development of either architecture products/resources or architecture-based functions/services in various areas for the ADO's APSE;
- To actively participate in development of the architecture practice supporting environment for the ADO, which will provide DSTO with opportunities to identify what is needed by the ADO in its future development; and
- To better use its leading position in architecture practice research for establishment of broad contacts and collaboration with R&D teams across the organisation and around the world.

12.6 Support from industry

Industry's capabilities in architecture have been developed over the last three decades supporting many individual activities in IT practice. These capabilities are mainly classified in four areas according to their different natures.

- System architecture solutions–e.g. 3-tiers, Client/Server, CORBA-based, Web-based, Component-based, Middleware, Messaging, ...
- Architectural methodologies/ enterprise architecture frameworks
- Software system development methodologies
- Tools/environments

These capabilities are available through two different types of providers:

- Consulting Services providers, including:
  - Solution providers – e.g. OOPL or CSC
  - Coaching services – e.g. Meta Group /Gartner Group
  - Concept studies (such as IT planning and technical options)
- Tool suppliers, including
  - CASE /architecture Tools – e.g. Rationale Rose/ System Architect/ Cool Family/ Ptech
  - Repository tools/Web-based publishing.

One of challenges facing the ADO is how to properly use these industry capabilities in an integrated manner and integrate them into the ADO's architecture practice and APSE.

12.7 Architecture practice working groups

Architecture practice involves considerable strategic decision making at an enterprise level.

Decisions on selection and development of architecture frameworks and enterprise supporting elements (such as a technical architecture framework) should be made by an architecture practice working group.

This working group needs to include representatives across the full spectrum of the defence organisation, so that the decisions made will be respected and effectively implemented. Without such broad representation, the diverse requirements of disparate parts of the organisation will not be properly addressed, resulting in inappropriate decisions that do not meet the needs of the organisation.

This group will have to play the key role in the following areas:

- Developing an architecture lexicon for the ADO's architecture practice;
- Making formal recommendations for the main decisions of the ARB;
- Providing support to the CIA and DIE Architecture Office;
- Organising the development of the APSE and documents to guide architecture practice.

13. What are the returns, risks and costs for architecture practice?

Like any activity in business, architecture practice can generate returns, operate with certain costs and face risks.

The most important return generated from the enterprise architecture practice is improved IT development capability and future organisation development capability. There are of course many other direct or indirect returns that have been discussed throughout this report.

It has been reported, however, that some research indicates that only 20% of an enterprise architecture is strategically valuable, which means the remaining 80% yields little reward. This finding shows that:

1) enterprise-wide architecture practice involves a lot of risks, predominantly in selection of architecture frameworks to be used and architecture products, and in particular those in the category of Enterprise Supporting Elements; and

2) wasting funds is quite possible in an ill-planned architecture practice, since a high level of complexity in architecture practice cannot guarantee a high level of maturity or success in the practice.

One of the main purposes of the Architecture Practice Study is to help the organisation to lift the rate of return by properly defining the context of architecture practice, targeting better objectives, and correctly selecting architecture products to be developed.

14. Recommendations

- The ARB should develop architecture practice concepts for the whole ADO at a level above individual architecture development, and give greater attention to architecture practice management, in order to generate long term benefits. The concepts should embody a mature understanding of architecture and lead to the development of a well-coordinated overall architecture approach specifically for the ADO architecture practice. This practice is aimed at generating an integrated architecture capability.
- Since the practice is focused towards generating the *capability* supporting future organisation development, a formal architecture product planning process should be defined in which future architecture development proposals must be reviewed and approved. To optimise architecture production and maximise the value of architecture, a consistent architecture value evaluation method should be introduced to make sure that an architecture is developed in the right context, at the right time and through an appropriate methodology.
- A well-developed Architecture Practice Supporting Environment (APSE) should be developed to deliver architecture capabilities in an integrated manner. A web-based repository, even only for a specific area like systems architecture, operational architectures or network communications architecture, can be a starting point or a prototype of such an environment and help to demonstrate architecture capabilities.
- Enterprise architecture issues, such as the enterprise technical architecture or other enterprise supporting or reference elements, are not independent of or isolated from the organisation's traditional R&D activities in IT. In order to achieve better integration, relevant parties need to ensure that outcomes of their work fit well into the context of the architecture practice and can be broadly beneficial to the community.
- Managing individual architecture development efforts is less complex than managing architecture practice and cannot lead to a complete enterprise architecture solution. The ARB's main interests should be in developing an architecture culture for the ADO, rather than just simply products.
- The ARB and DIEAO should consider reaching management solutions for the ADO architecture practice as important and necessary outcomes of their business. They need to find adequate resources to develop important documents to guide the selection and use of architecture frameworks and to formulate the evaluation process of architecture development proposals.
- It is important for the ADO to define an effective method for communicating architectures in its architecture practice, which allows the community developing and using architectures to visualise and understand architecture products in a consistent and standard manner. This would include an architecture lexicon to standardise use of terminology, and an easily-understood and well-accepted notational system for architecture representation.

The ADO should aim to achieve the following short term goals:

- Reach a common understanding that the ADO needs to not only produce architecture products, but also and more importantly a well-planned architecture practice.
- Develop methods for evaluation of architecture development proposals;
- Start to use the concept of architecture product management for improving generation, management and reuse of architecture knowledge;
- Define key architecture components at the enterprise level to reach a workable enterprise architecture framework as a basis for planning and coordination;
- Identify the main enterprise supporting elements, such as UJTL, MRO and (Enterprise) Technical Architecture, and Reference Models for communications and interoperability;
- Prepare technically and organisationally for conducting domain engineering related activities and developing a systems architecture repository;
- Establish working groups for development of the operational architecture subset and the technical architecture subset and their associated process guidelines; and
- Define interrelationship and connections between process and architecture frameworks to improve useability of individual methodologies.

The ADO should aim to achieve the following long term goals:

- Develop and maintain an architecture knowledge repository and enable its use in practice as much as possible;
- Choose a suitable existing approach if possible, or develop new architecture approaches or frameworks, for developing various architecture products in future organisation development;
- Develop architecture practice as part of the ADO's culture in its knowledge management and future organisation development;
- Ensure architecture and integration issues of large systems and projects are examined properly during the planning process;
- Develop supporting concepts/elements and tools/APSE for the integrated architecture business cycle illustrated in Figure 5-2, through using effective architecture product management and well-coordinated efforts; and
- Use architecture-based approaches and capabilities to integrate the responsibilities and interests of different business areas across the organisation in order to improve the IT development capability as whole.

15. Conclusions

This framework study systematically discusses architecture issues in the context of the whole Defence Organisation, and in particular those issues relating to supporting the evolutionary development of C4ISR systems. In doing so it strives to illustrate three critical roles of architecture:

- A picture of the current state;
- A blueprint or vision for the future; and
- A roadmap as guidance on how to get there.

Successful and full-scale use of architecture for all these three main purposes in an integrated manner is important for maturation of an organisation's IT development capability. In practice though, it is also very complicated and difficult to achieve in a systems of systems development context. These three roles cannot be played by any single architecture product no matter how comprehensive it is claimed to be by its developers. It is the architecture practice that can provide a context for all architecture-related activities to be planned, conducted, managed and coordinated towards achieving an integrated architecture-based capability. The ADO must develop its own architecture practice to optimise its architecture production and maximise the value of architecture.

Defining and developing proper strategies will help us not only in dealing with complexity in architecture, but will also have a significant impact on performance and cultural change of the ADO's IT practice. Although developing individual architecture products can generate certain architecture-based capabilities, they must be integrated in order to satisfy the broad needs of the ADO for improvement in its future development capability. What is required by the ADO for DIE development is an integrated architecture-based capability that is designed for supporting the improvement of IT development capability, and one that can successfully evolve over time and eventually become part of the organisation culture. That is a matured architecture culture in which any architecture is developed in a well-defined context, at the right time, through the use of an appropriate methodology, and is one that can be integrated with others and used broadly and effectively.

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Phase 1 - Client Report (Part 2)
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19. ABSTRACT

Successful development and evolution of the Defence Information Environment requires the organisation to develop an architectural culture in its Information Technology (IT) practice and future organisation development. In such a culture, the organisation must achieve an integrated architecture capability for high-level knowledge creation, management and reuse within its improved IT development capability. This report discusses the main issues facing the organisation in developing such an integrated architecture capability, and proposes employing architecture practice concepts at the level above individual architecture development. High-level management and integration solutions associated with architecture practice, and responsibilities of relevant parties are also discussed in the report to help reach a shared understanding of the practice required by the ADO. The report aims to provide a basis or context for the Architecture Review Board to plan and organise the architecture practice and to produce more detailed guidelines.